REPORT OF THE CHIEF OF THE BUREAU OF ENTOMOLOGY

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 30, 1931.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1931.

Respectfully,

C. L. MARLATT,
Entomologist and Chief of Bureau.

Hon. ARTHUR M. HYDE,
Secretary of Agriculture.

INTRODUCTION

The fiscal year has been characterized by important changes in the bureau's personnel and also by certain minor regroupings of activities, involving changes in the functional organization, some of which became effective within the year. It is expected that all these adjustments will be completed before the beginning of the season of active field operations for 1932.

CHANGES IN PERSONNEL

The retirement, October 15, 1927, of L. O. Howard from the position of Chief of the Bureau of Entomology was recorded in the annual report of that fiscal year. Doctor Howard was, however, retained in the bureau for four years beyond the retirement age, under provision of the retirement act, and during this period he prepared two books which in a sense summarize or are based on the work in economic entomology as developed in this and other countries. These are A History of Applied Entomology (1930), published by the Smithsonian Institution, and The Insect Menace, shortly to be issued by a commercial publisher. Doctor Howard's retirement from the bureau on June 30, 1931, closes his official connection with the department covering a period of some 53 years (1878–1931). A more extended statement of Doctor Howard's work was given in the Official Record of the department for July 4, 1931.

Mr. C. N. Ainslie, after 24 years of service in the bureau in work on insects affecting cereal and forage crops in the Middle West, having reached the maximum age limit, was retired October 31, 1930. His assignments have been important and his work, of great usefulness, has record in many reports and some 24 publications.

Early in the fiscal year L. B. Smith, principal entomologist, in charge of the Japanese beetle laboratory at Moorestown, N. J.,

resigned. Pending the reorganization of Japanese and Asiatic beetle investigations, W. R. Walton, of the Division of Cereal and Forage Insects, was placed in acting charge of the laboratory and field work. As part of the plan of reorganization of the bureau, already discussed, the Japanese and Asiatic beetle investigations were set up as a field division responsible directly to the chief of bureau. On December 16, 1930, C. H. Hadley was appointed to take charge of this work. Mr. Hadley came to the bureau by transfer from the Plant Quarantine and Control Administration, where he had been in charge of the Japanese beetle quarantine work since 1928. At an earlier period (1919–1923) he had been in charge of Japanese beetle work both as to research and quarantine enforcement.

Other important changes have been made in the bureau's personnel during the year. A. L. Quaintance, associate chief of bureau and chief of the Division of Deciduous Fruit Insects, resigned December 31, 1930. During his long connection with the bureau (1903–1930) he rendered a very notable service, the permanent record of which is the development of important work in his subject carried out by enthusiastic and competent personnel at stations established at strategic points in the United States, and the numerous bulletins, circulars, and other publications which have been issued under his own name, together with many others which have reported the work supervised by him at field stations.

So far the position of chief of the Division of Deciduous Fruit Insects has not been filled, but the work has been carried in the interim by the chief of bureau, assisted by B. A. Porter.

The position of chief of the Division of Cotton Insects, for many years held by B. R. Coad, was taken over February 10, 1931, by F. C. Bishopp, in an acting capacity, in addition to his responsibility as chief of the Division of Insects Affecting Man and Animals. Mr. Bishopp had been associated with the late W. D. Hunter, who for many years was in charge of cotton-insect work, and was familiar with the industry and its problems. On June 20, 1931, R. W. Harned, head of the State Plant Board of Mississippi, was appointed chief of the Cotton Insect Division. Mr. Harned is recognized as one of the outstanding entomologists in the country, has held many important offices in national scientific organizations, entomological and other, and is thoroughly familiar with the problems relating to insects injurious to cotton. It is believed that under his leadership research work in this field will be developed with increased vigor and effectiveness.

The position of Associate Chief of the Bureau of Entomology, made vacant by the resignation of Doctor Quaintance, has not been filled under that title, but what is substantially the equivalent of that position in duties and responsibility has been classified and established under the title of assistant chief of bureau. J. E. Graf was appointed to this new position February 21, and resigned March 4, 1931, to accept the newly created position of associate director of the United States National Museum. The loss of Mr. Graf was a serious one to the bureau, inasmuch as it vacated not only the position of assistant chief but also the position of chief of the important Division of Truck Crop Insects. This latter vacancy has not yet been filled, but in the interim the administration of this division is being carried by W. H. White as acting chief.

The position of assistant chief of bureau relinquished by Mr. Graf was filled by the appointment, April 1, 1931, of S. A. Rohwer, by transfer from a similar position in the Plant Quarantine and Control Administration of the Department of Agriculture. Mr. Rohwer entered the service of the Bureau of Entomology in 1909 in the Division of Forest Insects. He was later put in charge of the taxonomic work of the bureau in Hymenoptera, and afterwards took charge of the numerous bureau personnel engaged in taxonomic work. In 1927, in recognition of his administrative ability, he was appointed business manager of the bureau and in this position assisted the present chief of bureau in the reorganization of 1927–28 which resulted in assembling all the plant quarantine, regulatory, and general control work under the new unit entitled Plant Quarantine and Control Administration, of which unit he became assistant chief July 1, 1928. Mr. Rohwer is a technical entomologist, and his long experience in the bureau in research and in administrative work has well fitted him for the position which he now holds. The duties of assistant chief of bureau as now classified are to assist the chief of bureau in the direction of all investigational and research work.

To replace the old position of assistant chief in charge of business management a new position has been set up—that of chief of the section of administration—to take charge, under the direction of the chief of bureau, of all business and personnel matters. This position was filled on March 6 by the appointment of Frank H. Spencer, who for the last six years has been administrative assistant to the Secretary of Agriculture, and prior to that time had held other administrative positions in the department.

A. C. Baker will be transferred to Mexico City, where he will direct the laboratory established there by the bureau in 1928 for investigating, in cooperation with the Department of Agriculture of Mexico, fruit flies and other tropical insect pests. Doctor Baker has on various occasions expressed a wish to devote the major part of his time to research, which his duties in administering widely scattered sections made impossible, and in the field of research has expressed a preference for the very important station which he had established in Mexico City. Inasmuch as the Mexico City station has recently lost several of its important research personnel, the time was particularly favorable to give Doctor Baker this opportunity. It is expected, however, that he will remain in close contact with all the work of the bureau dealing with tropical fruit flies and other tropical insects, and that he will cooperate in planning the research on these problems carried on at the bureau laboratories in the Canal Zone and in Hawaii.

CHANGES IN DIVISIONAL CLASSIFICATION OF WORK

The changes in administrative structure of the bureau, referred to above, indicated this as a favorable time for minor reorganization of the subject matter of the bureau in its divisional classification. This reorganization became effective in part during the fiscal year 1931, and it is expected that the adjustments will be fully completed before the active season of 1932 begins. The reorganization will be reflected in the classification of work and in the appropriation

language for the fiscal year 1933. Its purpose is to bring together related activities or activities which involve related control methods. The principal change involved is the elimination of the Division of Tropical, Subtropical, and Ornamental Plant Insects and the distribution of its component elements to other existing divisions. The changes in the distribution of subject matter of the bureau resulting from the reorganization are as follows: (1) The Division of Deciduous Fruit Insects becomes the Division of Insects Affecting Fruit and Shade Trees and includes citrus and other subtropical fruits in addition to deciduous fruits, while, by transfer from the Division of Forest Insects, it assumes all work involving shade and ornamental trees and shrubs, which, both as to insect enemies and control measures, is closely related to orchard operations. (2) The Division of Truck Crop Insects becomes the Division of Insects Affecting Truck and Garden Crops, to include, in addition to truck crops, insects affecting greenhouse plants, bulbs, roses, and other florist stock. (3) The Division of Insects Affecting Stored Products, including household pests, is enlarged by transfer from the Division of Forest Insects of the section dealing with termites and certain other insects attacking wood in buildings, furniture, and stored finished-wood products. To this division also will be added the new appropriation available July 1 for the study of control of the Argentine ant, whose major importance is as a household pest. (4) The appropriation item Taxonomy and Interrelations of Insects includes important basic subjects necessary for the conduct of much of the bureau's economic work but heretofore carried on in other divisions without specific leadership. The subjects grouped together are not necessarily closely related and the assemblage under one item is purely for administrative purposes. These subjects are as follows: (1) Taxonomic investigations, (2) insect pest survey, (3) public relations, (4) bioclimatics, (5) morphological investigations, (6) exchange of useful insects, (7) physiology and toxicology, (8) disinfection, and (9) insect diseases.

BUDGET INCREASES

The Budget for the fiscal year 1931 includes increases totaling $329,440 for old and continuing subjects and for undertaking new lines of work. No reductions were made in funds for activities already under way.

NEW SUBJECTS

The more important increases for new work may be summarized as follows: For large-scale tests to determine value of bait traps against the oriental fruit moth, $50,000; for investigating the life history, habits, and means of controlling the cyclamen mite, $5,000; for experiments relating to the control of resistant scale insects affecting citrus fruits, $25,000; for investigations of the pea weevil, $5,000; for development of methods for the control of wireworms in the Pacific Northwest, $25,000; for developing methods of control of wireworms in South Carolina, $7,500; for devising control methods for the Lima-bean pod borer, $7,500; for investigating the control of the range caterpillar, $10,000; for determining means of controlling mosquitoes in Oregon, $10,000; for investigation of ticks

and tick parasites, $5,000; for initiating investigations of sand flies, $16,100; for study of reindeer insects in Alaska, $6,000; for investigations of the tobacco or cigarette beetle, $10,000; for investigations of insect pests injurious to confections and nut meats, $5,000; for the identification of plant bugs, $4,000; for initiating work of a special unit which will expedite the distribution of information on pest control to farmers, fruit growers, and livestock producers, $14,740; for studies on the preparation of honey for market, $5,600; and for apiary investigations in the Pacific Coast States, $15,000.

OLDER OR CONTINUING SUBJECTS

For expanding the apple-insect work at Yakima, Wash., and other places in the Pacific Northwest, $5,000; for enlarging pecan-insect work, $8,000; for collecting, rearing, and shipping to the United States, parasites of the Japanese and Asiatic beetles from Australia and Europe, $20,000; for enlarging the investigations on the oriental fruit moth and plum curculio in southern peach orchards, $8,420; for furthering the investigation of control measures for the strawberry root aphid, $3,940; for investigating the control of tree-killing bark beetles in the Western States, $10,210; for investigating the control of insects injuring shade and park trees, $5,790; for investigating the habits and control of the alfalfa weevil in southern Oregon, $4,380; for enlarging the investigations of leaf hoppers and other insects involved in diseaselike injury to alfalfa, clover, and similar forage legumes, $10,000; for expediting the importation and colonization of sugarcane-borer parasites, $10,000; for enlarging investigations on clothes moths, $10,000; for identifying mosquitoes and other blood-sucking flies, $6,000; for employing clerical assistance necessitated by the growth of the insect pest survey, $1,260.

DECIDUOUS FRUIT INSECTS

PEACH INSECTS

The major peach insects under investigation have been the oriental fruit moth and the plum curculio. A new laboratory was established in the spring of 1930 at Harriman, Tenn., for the purpose of investigating both of these insects, which in recent years have caused serious losses to Tennessee peach growers. Other peach insects of lesser importance will also be investigated under conditions which exist in eastern Tennessee.

ORIENTAL FRUIT MOTH

The oriental fruit moth continues to provide one of the most difficult fruit-insect problems under investigation. Thus far the entomologists working on this pest have been unable to recommend practical means of control to the growers.

Certain phases of the biology of the oriental fruit moth are being investigated further. Particular attention is being given to the dissemination habits of the moths. Numerous releases of marked moths reared from material collected in the orchards are being made in the large areas in which bait traps are maintained, as well as in other areas. Screens covered with sticky material have also been erected

at several points for capturing marked moths. This work is only well under way, but the results thus far indicate that many of the moths move rather freely from point to point and do not remain close to the place where they emerged. The information resulting from these studies will have an important bearing on the application of any control measures which may be developed. It will also be a valuable aid in laying out experimental plats and in interpreting the results of control experiments.

Previous efforts to control the fruit moth by means of insecticides have given very discouraging results. Insecticide studies are being continued, however, at the Vincennes, Ind., and the Takoma Park, Md., stations. Most of this work is conducted in the laboratory, and at present there is little of a positive nature to report.

Special emphasis has again been placed on the biological control of the oriental fruit moth, because of the absence of adequate insecticidal control measures. In the eastern areas, in which the fruit moth has been present for the longest period of time, the early-season twig-infesting broods of larvæ are very much reduced in numbers by numerous native parasites. The work of introducing these parasites into other areas, from which they have been found to be absent, has been continued on an increasing scale. It is hoped that the parasites thus introduced will cause a progressive decrease in the oriental fruit-moth population, and a corresponding decrease in the economic losses it causes.

Adults of *Macrocentrus ancylivora* Rohwer, one of the most important native fruit-moth parasites in the Eastern States, have been shipped successfully from there to southern Illinois, a distance of more than 800 miles. By packing the containers used for shipping adults of this species in ice-cream tubs, packed with sawdust and ice, the insects can be maintained at temperatures of 45° to 50° F. for two or three days. Under these conditions they reach all destinations in the eastern half of the United States with a negligible mortality. From material reared at the Moorestown, N. J., laboratory 86 colonies comprising nearly 25,000 adults of *Macrocentrus ancylivora* were shipped during 1930, and colonized in various peach-growing sections in 13 States, chiefly east of the Mississippi River. Similar liberations are being made this season. Recovery collections made thus far have indicated that a high percentage of the liberations have been successful.

The parasite work is being carried on in close cooperation with various State organizations, which have in many cases furnished funds and labor for collecting material with the purpose of benefiting the peach industry within their borders. Large numbers of oriental fruit moth and strawberry leaf-roller larvæ parasitized by Macrocentrus have been collected under the supervision of bureau representatives and shipped to the interested State organizations.

Six colonies of adults of another parasite, *Glypta rufiscutellaris* Cress., including some 1,526 parasites, have been liberated in peach orchards in Georgia and the Carolinas. Four experimental liberations of 1,752 adults of *Pristomerus ocellatus* Cush., a fruit-moth parasite found in New Jersey, have also been made at points in northern Georgia, eastern Tennessee, and southern Indiana.

Mass rearing of *Trichogramma minutum* Riley is also being conducted in an effort to ascertain the value of liberations of these parasites in peach orchards. It has been found that during the winter, spring, and early summer the eggs of the native bagworm, kept in cold storage, provide an economical medium for mass rearing of Trichogramma.

In order to provide a sound basis for a more intelligent distribution of these parasites, a more comprehensive parasite survey than any hitherto undertaken is being conducted, in combination with recovery collections at points where liberations have previously been made.

The Bureau of Entomology has for the last two years maintained an investigator in southern France and northern Italy, in the hope of obtaining additional valuable parasites of the fruit moth. Shipments have already been made of four species of European parasites, including *Pristomerus vulnerator* Panz., *Apanteles anarsiae* F. and A., *Zenillia roseanae* B. and B., and *Ascogaster quadridentatus* Wesm. The last-named species is considered by some authors to be identical with *A. carpocapsae* Vier., which attacks both the oriental fruit moth and the codling moth in the United States. The form *quadridentatus*, however, appears to attack the oriental fruit moth more freely in Europe than does *carpocapsae* in the United States. *A. quadridentatus* has been successfully carried over the winter in the United States. *P. vulnerator* was liberated in cages and in the open at Moorestown, N. J., in the spring of 1931, under very favorable conditions, although there appears to be some doubt whether the species has established itself.

As a by-product of the European parasite work, shipments have been made of *Copidosoma pyralidis* Ashm., an important European parasite of the peach twig borer, *Anarsia lineatella* Zell. These were received at New York and immediately forwarded by air mail to State officials in California, where the peach twig borer is an important pest. One of these colonies was shipped from southern France to California in only 12 days, and reached its destination in perfect condition. Shipments of *Macrocentrus ancylivora* have also been made from the United States to France in order to aid in the natural control of the fruit moth in that country.

In last year's report mention was made of the large-scale bait-trap work authorized by Congress in the first deficiency act of 1930. This appropriation provided for two large-scale experimental tests of the use of traps, filled with various attractive substances, for the control of the oriental fruit moth. When used by individual growers, the bait traps have caught large numbers of moths, but have failed to show material benefit to the individual orchard concerned. Possibly this has been because many additional moths were attracted to the orchard from unbaited orchards. The large-scale experiments were for the purpose of determining the value of the baits when used over an extensive acreage.

Those conducted during the season of 1930 were inconclusive, because of the absence of a peach crop in Indiana and the unexpected lightness of the infestation at both Vincennes, Ind., and Cornelia, Ga., the localities in which the work was conducted. In the latter district the moth population within the baited area, as

indicated by fruit-infestation records and by counts of injured twigs, was only one-half of that in the surrounding unbaited area. At Vincennes, however, the infestation in the baited area, as indicated by counts of injured twigs, was slightly greater than that outside the area.

On account of the abnormal conditions under which the large-scale tests were carried on in 1930, provision was made by Congress for their continuation for another season. It is of course too early to predict the outcome of this year's tests, although at Cornelia, Ga., the infestation in the unbaited area appears at the present writing (July, 1931) to be increasing much more rapidly than that in the baited area.

During the early season of 1931 the infestation was extremely light in both Georgia and Indiana. The moth population may build up to significant numbers by the end of the season, however, since the heavy peach crop which is present in both regions in which this work is under way provides an abundant food supply.

The project this season has been modified to provide a greater number of comparative tests of different bait materials. These experiments include comparisons of various grades of sugar and molasses, numerous aromatic chemicals, and various strengths of these materials. The results obtained thus far indicate rather definitely that the medium to lower grades of brown sugar and the higher grades of molasses make the most attractive baits.

In order to obtain information on the proportion of the moth population which is caught, the movements of the moths, and the distances which they normally travel, as well as the distances to which they are attracted by the traps, small numbers of marked moths reared from larvæ collected within the area have been liberated. The percentage of recovery has ranged from 28 per cent during cold, unfavorable weather, when the moths are comparatively inactive, to 80 per cent under more favorable conditions. In one case 20 out of 50 marked moths were recovered the night following their release, the bait solutions in this case being three weeks old. Several moths liberated a quarter of a mile from any traps were recaptured in the traps. One moth traveled more than a mile in six days. These experiments and observations are furnishing valuable information on the dissemination habits of the moths and on their behavior in areas in which traps are maintained.

PLUM CURCULIO

Mention was made in the last annual report of the extremely severe infestation of the plum curculio in southern peach orchards in the summer of 1929. A remarkable reduction in the infestation has since occurred, largely because of three major factors: (1) The emergence of adults from hibernation in the spring of 1930 was later than usual, which reduced the second brood to much less than normal numbers. (2) The early summer of 1930 was extremely hot and dry, a condition very unfavorable to the insect when in the pupal stage in the ground. This caused a further reduction in the general curculio population. (3) The control measures recommended by the Bureau of Entomology were carried out with an unusual degree

of thoroughness. For the most part these conditions have been duplicated in the early season of 1931, and as a result the curculio infestation is now at an extremely low ebb.

Earlier tests having shown that potassium fluosilicate offers promise as a substitute for lead arsenate in the control of the plum curculio on peach, this season's tests at both Fort Valley, Ga., and Harriman, Tenn., included large plats sprayed with this material. Thus far no foliage injury of consequence has developed. The results in curculio control have not yet been recorded. Barium fluosilicate and cryolite, which have shown some promise as substitutes for lead arsenate, and which were reported on favorably by the Tennessee Agricultural Experiment Station last year, are also being tested on a field scale at the Harriman, Tenn., laboratory.

Possible supplementary means of controlling the curculio are also under investigation, particularly at the Fort Valley laboratory. The burial of curculio-infested peach drops, which is sometimes suggested, has been found unreliable, since adult curculios have emerged this season from drops which were buried to a depth of 3 feet, and adults have emerged in considerable numbers from a depth of 1½ to 2 feet. Submerging infested drops in water for short periods of time has been found to have very little effect upon the curculio larvæ, although after a period of 28 days practically all of them were killed. It has been found that the exposure of peach drops on the ground to the direct rays of the sun is fatal to all larvæ within them.

A number of soil treatments for the control of larvæ and pupæ are being given preliminary tests. The most promising of these treatments is spraying the soil with a 4 per cent emulsion of mineral oil in which paradichlorobenzene has been dissolved. This has been found 100 per cent effective against the pupæ in the soil.

A new lightweight curculio-jarring sheet was devised by the staff of the Fort Valley laboratory during the year, and a brief article describing this has been published.

OTHER PEACH INSECTS

Some attention has been devoted to various other peach insects, particularly to the peach borer (*Synanthedon exitiosa* Say) and the lesser peach tree borer (*S. pictipes* G. and R.). Paradichlorobenzene dissolved in cottonseed oil (2 pounds of the chemical in 1 gallon of oil) has continued to give very satisfactory results in the control of the lesser peach borer. While recommended for use chiefly on those parts of the trees injured by the borers, this solution has also been applied to the trunk and branches of young uninfested trees without any apparent injury. It has also been found effective against the shot-hole borer on peach trees.

Emulsions of cottonseed oil in which paradichlorobenzene has been dissolved have given perfect control of larvæ of the peach borer in 1, 2, and 3 year old trees when applied in such quantities that one-fourth to one-half ounce of paradichlorobenzene was placed on each tree. No sign of injury to these trees has yet resulted from this treatment, whereas the use of paradichlorobenzene crystals, as recommended for older trees, has frequently caused injury to trees 1 year,

2 years, and 3 years old under conditions found in Georgia. Because of the danger of injury by the chemical, the use of the worming knife has been recommended for controlling the peach borer on young trees. The use of the paradichlorobenzene solution promises to be much more satisfactory on older trees as well as on young trees, since it considerably reduces the labor cost. Detailed studies of the biology of the peach borer are under way at the stations at Fort Valley, Ga., and Harriman, Tenn.

Experiments dealing with the susceptibility of peach trees to oil sprays have been continued. No injury has occurred in any case from the application of the soap-lubricating-oil emulsion up to a strength of 8 per cent, although some injury has developed in the trees treated with a strength of 10 per cent or more. One tree which had received five annual applications of 12 per cent oil has died. These results mean that the ordinary recommended strength of not more than 3 per cent of oil appears very safe under conditions in Georgia.

APPLE INSECTS

CODLING MOTH

The search for insecticide materials that will give effective control of the codling moth without leaving objectionable residue on the fruit has been continued. The need for such an effective and satisfactory substitute for lead arsenate is becoming progressively greater, because of the continued reduction in the quantity of arsenical residue tolerated on fruit entering interstate commerce, but the problem of finding such a material is proving extremely difficult. At present the situation is met by washing the fruit in either dilute acid or alkali, but the problem can not be considered finally solved until a poison is found that effectively controls the codling moth and yet leaves no objectionable residue.

The most encouraging development in the codling-moth problem has been the continued good results obtained in the Northwest with certain fluorine compounds. Two of these in particular, barium fluosilicate, and cryolite, sometimes referred to as sodium fluoaluminate, gave very satisfactory results in the field tests conducted in 1930, and observations in the early summer of 1931 in the plats sprayed with the same materials indicate that results will probably be equally good in 1931. This year's tests also include a potassium fluoaluminate and potassium fluosilicate, two other flourine compounds which offer promise in the Northwest. In the more humid sections in the East the fluorine compounds have in previous years proved inadequate for the control of the codling moth, but the encouraging results obtained in the arid western regions suggest that with further study it may be possible to adapt these materials to use under more humid conditions.

No definite tolerance of the fluorine compounds which will be permitted on food products has been announced by the Food and Drug Administration, and in the absence of such information growers in the Northwest are being advised against substituting such materials for lead arsenate in the entire spray schedule. The information which has been obtained about them is, however, being placed before these growers with the suggestion that the fluorine materials may be

worth trying on a small commercial scale in the spray applications against the second brood of worms. Used in this way, neither lead arsenate nor the fluorine compound will be present at harvest time in sufficient quantity to be difficult to remove by means of hydrochloric acid.

The codling-moth work in the Northwest has been cooperative with the Bureau of Chemistry and Soils, as well as with the Bureau of Plant Industry. The former organization has stationed chemists at the Yakima, Wash., laboratory during the past few seasons. In addition to making analyses of sprayed fruit, the chemists have been especially helpful in the investigations of the fluorine compounds. The members of the Bureau of Plant Industry have also cooperated in several phases of the work.

Mixtures of nicotine sulphate with dilute "white oil" emulsions have continued to give fairly good results against second-brood worms in the Northwest, but in other parts of the country the results have been less satisfactory and there appears to be serious doubt whether these combinations will be effective in such sections. Tests of insoluble compounds of nicotine, such as nicotine tannate, have been continued in an effort to discover a form of nicotine that will not wash off in rainy weather, and that will not volatilize too rapidly. The results of these tests thus far have been none too encouraging.

Tests of rotenone have been continued, but results have been disappointing. Because of the high initial toxicity which this material possesses, however, efforts to develop ways of effectively utilizing it are being continued.

Cuprous cyanide, which gave fairly good results in the season of 1929, is being tested further in the season of 1931.

Manganese arsenate was tested on a field scale at several points, in order to obtain further information on the possibility of using it as a substitute for lead arsenate. This would eliminate the objectionable lead portion of the material, even if the arsenical residue were not reduced. The results in codling-moth control have been so poor that manganese arsenate can not be recommended.

The Yakima, Wash., laboratory has cooperated with a number of workers in the Pacific Northwest in a group effort known as the Northwestern cooperative oil-spray project, in testing the various highly refined oils, and combinations of such oils with other materials, against the codling moth. The results of this effort are proving very much worth while, and on them as a basis definite recommendations are drawn up at the close of each season as a guide to commercial growers in working out their spray program.

The field station at Wichita, Kans., will be discontinued at the end of 1931. This laboratory was established in the spring of 1926, in cooperation with the Kansas Agricultural Experiment Station, in order to meet the emergency caused by an extremely severe codling-moth infestation. The work of the Wichita station has shown definitely that under the conditions existing in the Arkansas River Valley the codling moth may profitably be controlled by heavy, thorough, frequent, and timely applications of lead arsenate, although this necessitates washing the fruit to remove the residue. Considerable study at this laboratory has also been given to the distribution of the codling moth in orchards, both from point to

point within an orchard and in the various parts of individual trees. This study is likewise to be completed by the close of this season.

Intensive laboratory testing of large numbers of possible new insecticides for the control of the codling moth has been conducted at the laboratories at Takoma Park, Md., Vincennes, Ind., and Yakima, Wash. During the season of 1930 more than 200 different insecticide materials or combinations were tested at the Vincennes laboratory. At this laboratory a very satisfactory technic for obtaining newly hatched codling-moth larvæ has been developed. During the season of 1930 more than 125,000 larvæ were used in the tests at Vincennes, and in June, 1931, more than 70,000 were used in the insecticide studies. With the exception of certain fluorine compounds, and certain organic chemicals which were found to be injurious to apple foliage, nothing was found approaching lead arsenate in toxicity to codling-moth larvæ.

Further tests of chemically treated bands continue to indicate that these constitute a valuable adjunct to spraying. Work with these bands has been centered at Takoma Park, Md., and field testing has been done at a number of stations, including Yakima, Wash.; Wenatchee, Wash.; Vincennes, Ind.; Wichita, Kans.; and Bentonville, Ark. Bands treated with beta-naphthol, lubricating oil, and aluminum stearate have killed practically 100 per cent of all worms entering them. No evidence of a repellent effect has been found. Similar tests conducted by numerous State workers in cooperation with the Bureau of Entomology have corroborated these results. This season bands of various widths are being tested in order to determine the width most effective in trapping codling-moth larvæ.

The parasite survey which was undertaken some two years ago is being completed with the emergence in the spring of 1931 of material collected during 1930. In this way a great deal of information has been accumulated on the distribution and present importance of the various species of parasites of the codling moth in different parts of the country. One of the most important parasites in the Eastern States, *Ascogaster carpocapsae*, was found to be absent from most sections west of the Mississippi. Shipments of this parasite have already been made to Wichita, Kans., and Bentonville, Ark., in the effort to establish it at those points. While immediately measurable results are not expected, the presence of this parasite should prove a valuable factor tending to limit the codling-moth population. As already mentioned in previous reports, this parasite was introduced several years ago into the Pacific Northwest.

The studies of codling-moth biology at Bentonville, Ark., have been continued as previously outlined.

RELATION OF INSECTS TO PERENNIAL CANKER OF APPLE

Studies of the relation of insects to the perennial canker of apple, a fungous disease which seriously attacks certain varieties of apple in the Pacific Northwest, were undertaken at Wenatchee, Wash., in the spring of 1930. This disease assumes the form of cankers which originate in pruning or other wounds. The canker extends itself from year to year, and ultimately girdles and kills the twigs and branches. The cankers also provide an entrance point for rot fungi,

which hasten the death of large branches or of entire trees. The perennial canker fungus also causes a storage rot of mature fruit.

The cankers caused by this disease are usually infested by the woolly apple aphid (*Eriosoma lanigerum* Hausm.) and certain investigators of this disease believe that the woolly aphid is chiefly responsible for its spread and its persistence from year to year in the cankers.

The first object of the investigations under way is to determine the exact relation of the woolly aphid to the disease. Because of the mildness of the winter of 1930–31, the experiments which have been conducted thus far have failed to demonstrate this relationship, the disease being serious only after severe winters. On the assumption that the woolly aphid is at least an important factor, the investigations include studies of preventing woolly-aphid infestation in the cankers, by various means such as the use of paints, wound dressings, and so on.

As one possible means of reducing the woolly-aphid population in the Northwest, an effort is being made to introduce the parasite *Aphelinus mali* Hald. into that section. Several shipments of these parasites have been received through the courtesy of the Canadian parasite laboratory at Belleville, Ontario. The parasites received have been caged with colonies of the woolly aphid and it appears very probable that they will successfully establish themselves.

The status of a canker-infesting insect known as *Epicallima coloradella* Wals. in relation to the canker disease has also been studied.

OTHER APPLE INSECTS

Studies of the biology and control of the various species of apple leaf hoppers have been continued at the Bentonville, Ark., laboratory. One manuscript covering much of the work on these insects is already in press, and a second manuscript is to be submitted shortly. Studies are also being made at Bentonville of the giant root borer *Prionus imbricornis* L., which has become increasingly destructive to apple trees in northwestern Arkansas. The observations made in 1930 have revealed marked differences from the published accounts of the biology of this species. Numerous materials were tested for possible value in the control of this species, but only mercuric chloride gave any evidence of destroying the borers. During the present season experiments are being conducted on measures for the destruction of the adults.

In the Pacific Northwest serious outbreaks of the tarnished plant bug in orchards have occurred during the past two or three seasons. This bug hibernates in the adult stage, and emerges from its winter quarters in the early spring at a time when the buds of apple and other fruits are often the most attractive food material available. Its punctures cause many of the blossoms and the newly set fruit to drop off, and the fruit developing from the injured buds which remain is considerably distorted. This species breeds almost entirely on herbaceous vegetation, and the presence of alfalfa and sweetclover in or close to the orchards seems to have resulted in the building up of a very numerous population. Sweetclover in particular is too

valuable as a cover crop to permit recommending its elimination. The problem is being given as much attention as is permitted by the other work under way.

NUT INSECTS

PECAN NUT CASE-BEARER

The pecan nut case-bearer (*Acrobasis caryae* Grote), which was unusually abundant in the season of 1930 in many pecan sections, and which caused a further reduction of the light crop of nuts borne in the orchards in the southeastern part of the United States, has been practically absent this season in that section, although causing more or less damage in other areas.

As noted in last year's report, the nut case-bearer is not readily controlled by spraying or dusting with stomach poisons. Because of the serious losses which occurred in 1930 in the Southeastern States, the Albany, Ga., laboratory, in the late fall of 1930, undertook intensive studies of the biological control of this pest as well as of other pecan insects. The first activity undertaken has been the large-scale rearing of *Trichogramma minutum* Riley, and an attempt to utilize this parasite in the field to control the nut case-bearer. Up to the close of June a total of more than 13,000,000 Trichogramma had been reared, and liberations had been made in seven different orchards at appropriate times for the control of the eggs of this insect. Because of the virtual absence of the nut case-bearer, the results this season will be inconclusive as to practical control. At the Albany laboratory studies are also being made of *Phanerotoma tibialis* Hald., a parasite which oviposits in the eggs of the nut case-bearer and of numerous other pecan insects, the parasite later developing in the larvæ of the host insect.

Similar parasite studies are being conducted at the laboratory at Brownwood, Tex. In the Texas area the pecan groves consist mostly of native seedling growth in the river bottoms and along watercourses. Under these conditions biological control is of particular importance, and the utilization of Trichogramma under the semiarid conditions which exist there is being studied. Studies have also been made of 25 or more native parasites and predators of the nut case-bearer, many of which also attack the shuck worm and other pecan insects. These studies will prove of great value as a basis for subsequent work of a more intensive nature.

Experimental work with possible insecticidal means of control has been continued, chiefly in the use of contact materials against the eggs. Because of the extreme lightness of the infestation, the results this season have been inconclusive.

PECAN LEAF CASE-BEARER

Further experiments have confirmed earlier findings that Bordeaux mixture, 3–4–50, is a very satisfactory corrective for preventing foliage injury by lead arsenate in spraying pecans for the control of the leaf case-bearer (*Acrobasis palliolella* Rag.). Additional evidence was also obtained indicating that calcium arsenate, when used with Bordeaux mixture, is fully as safe and as effective as lead arsenate, at a considerable saving in cost. The combination

of Bordeaux mixture and calcium arsenate reduced the infestation in one test from 35 per cent to 3 per cent, and in a second series of plats from 36 per cent to 2 per cent.

HICKORY SHUCK WORM

This is another pecan insect which is not readily controllable by the usual stomach poisons, since it has feeding habits very similar to those of the nut case-bearer, as well as those of its near relative, the oriental fruit moth. Tests conducted at the Albany, Ga., laboratory on egg-destroying materials, including the highly refined oil sprays at 1 per cent, and lubricating-oil emulsion 1 per cent with nicotine sulphate 1–1,000, gave some reduction of infestation but not enough benefit to justify its cost.

Cultural methods offer the greatest promise of success in controlling the shuck worm, particularly the disposal of the shucks in which the insect passes the winter. Experiments with various harvesting practices are under way in order to work out the most effective and economical means of disposing of the shucks.

The possible utilization of Trichogramma in controlling the shuck worm is also being investigated, and experimental liberations have been made in several orchards.

PECAN WEEVIL

Cage experiments and field trials conducted at Experiment, Ga., have indicated that pecans may be protected from weevil attack by spraying with hydrated lime. In field tests, sprayed trees had an infestation of 2 per cent (including all nuts on trees, drops, and harvest, after July 24) as compared with 10 per cent infestation of unsprayed trees. Because of variations within the experimental plats, however, these tests must be repeated before conclusions may be drawn.

Throughout the period of their activity adult weevils are readily jarred from heavily infested trees, and damage to pecan nuts was appreciably lessened by this procedure. Jarring should be done at least once a week, with extra jarrings 24 to 48 hours after each rainfall of one-half inch or more. During the first half of the period, or up to September 1, it is necessary to strike only the limbs within 8 or 10 feet of the ground in order to get most of the weevils; after that time weevils are present at higher points in the trees. The insects can be jarred from the limbs by strokes that are not heavy enough to dislodge sound nuts. In an orchard of lightly infested trees, however, jarring did not prove profitable.

Studies of the effects of various systems of culture on the mortality of the larvæ after they leave the nuts are also being made.

OBSCURE SCALE

Studies of the obscure scale (*Chrysomphalus obscurus* Comst.) have been conducted at the Shreveport, La., laboratory. The biology of this insect under Louisiana conditions has now been worked out, and extensive records have been made of the parasites affecting it. Experimental spraying has demonstrated that oil emulsion should

be used at a strength of at least 6 per cent to control the obscure scale, and even this concentration does not give a perfect kill. A few pecan trees very heavily sprayed with a 6 per cent lubricating-oil emulsion in December were considerably injured, and slight injury occurred on a few trees similarly sprayed in February. No injury resulted from applications of oil emulsion at this strength on April 1. This suggests that pecan trees are less susceptible to oil injury as the close of the dormant period approaches, and that spraying for the obscure scale should be done in late spring.

OTHER PECAN INSECTS

Further attention has been given to the black pecan aphid, with particular reference to the possibility of reducing the cost of spray materials. Taxonomic and morphological studies of the various aphids affecting the pecan are being made at the station at Experiment, Ga.

Certain species of Phylloxera (chiefly *Phylloxera devastatrix* Pergande) have been found seriously injuring pecans in southern Louisiana. While it has been impossible to give this problem a great deal of attention, preliminary observations have been made. It is planned to conduct tests next year with applications of contact materials just as the buds are pushing out, since it is believed that the insect may be controlled by spraying at that time, before there has been opportunity for the formation of galls.

Observations are being made on the bottle leaf case-bearer (*Acrobasis cunulae* Heinrich), found on pecans comparatively recently, but quite abundant in the section south of Albany, Ga.

Leaf-feeding insects are often found damaging pecan foliage at about the time when the pistillate bloom is becoming evident, and immediate spray applications are needed to prevent further injury. This is particularly true in southern Louisiana. Many pecan growers have hesitated to spray at this time for fear of damaging the tender pistillate bloom. Detailed experiments conducted in the spring of 1931 have indicated that spraying may safely be done during the blooming period, if leaf-chewing insects are causing serious damage.

CHESTNUT WEEVILS

Further experiments with the use of hydrated lime in the control of chestnut weevils (*Curculio proboscideus* Fab. and *C. auriger* Casey) have given encouraging results. In experiments conducted at Bell Station, Md., two applications of a heavy lime spray, with the addition of a small quantity of fish-oil soap for a sticker, appeared to reduce the infestation from 44 per cent to less than 2 per cent. A single application made at Fairfax, Va., under conditions of very severe infestation gave a distinct reduction in the number of wormy chestnuts, although not enough to constitute satisfactory commercial control. It is believed that two applications would have given much better results.

Dusting with hydrated lime, as well as dusting with powdered talc, gave appreciable reductions in infestation. These materials, however, did not adhere so well as appears desirable.

BLUEBERRY MAGGOT

Dusting with calcium arsenate, now recommended for control of the blueberry maggot as a result of investigations conducted by the Bureau of Entomology, continued to give very satisfactory control during 1930, in the face of a severe infestation in untreated areas. Properly timed, two applications of calcium arsenate dust, at the rate of approximately 6 pounds per acre with each application, have given reductions in infestation ranging from 85 to 98 per cent.

The use of insecticide materials for the control of this pest is a rather new practice in the protection of native blueberries. Full information on present recommendations has been placed at the disposal of the blueberry growers of Maine by means of addresses at meetings, the preparation of a mimeographed circular which has been distributed by the University of Maine, and by personal contacts. A detailed publication reporting the results of the biological and control studies which have been made for a number of years is now in press, and a circular has been prepared summarizing the practical recommendations now being made.

The control experiments are being continued. This season they include tests of more dilute dusts, in which the calcium arsenate is mixed with an equal quantity or more of hydrated lime as a carrier. Copper carbonate, a dust containing arsenic, copper, and lime, and other materials are also being tested as possible substitutes for calcium arsenate. The arsenic-copper-lime dust is being tested as a control of both the maggot and leaf diseases, in cooperation with the Maine Agricultural Experiment Station.

Large plats, treated according to standard recommendations, are being maintained in order to confirm previous results and to check on the accuracy of the timing of the applications.

While the biological studies on the blueberry maggot have been practically completed, records are still being taken of the period of emergence and other important features of the pest's seasonal development. During the period 1926 to 1929 the flies emerged at practically the same dates, with variations of very few days from year to year. In 1930, however, the emergence was a week to 10 days earlier than had previously been observed. This information was given to the growers in order to assist them in timing their dust applications.

An interesting feature of the life-history studies was the discovery that some of the maggots remain in the ground through at least four winters, so that a few flies emerge each year from puparia that were formed in the ground four summers earlier. The emergence from puparia which have been two or more winters in the soil has been found to be five or six days later than the emergence from puparia which have spent only one winter in the soil.

Incidental studies are being made of other blueberry insects, particularly of a gall-making insect, *Hemadas nubilipennis* Ashmead, which is causing considerable damage in a few localities.

GRAPE INSECTS

The work with grape insects at Sandusky, Ohio, has been carried on in cooperation with the Ohio Agricultural Experiment Station.

Spray residue on grapes, resulting from the applications made for the control of the grape berry moth, continues to offer a problem of major importance in northern Ohio. Several fluorine compounds mentioned in last year's report, including the fluoaluminates of sodium, barium, and calcium, as well as the fluosilicates of the same elements, have been tested further, chiefly for foliage reactions. For the most part they have proved injurious to grape foliage. Several contact materials, including oil emulsions, nicotine sulphate, and derris and pyrethrum extracts, as well as rotenone, one of the most important active ingredients of derris, have been tested against the second brood of worms with very disappointing results. Experiments in modifying cultural methods which might aid in the control of the berry moth are being continued. Further study is needed, however, before recommendations can be made.

Because of the nature of the fruit, it has been found more difficult to remove arsenical residue from grapes than from apples. The Bureau of Entomology has continued to cooperate with representatives of the Food and Drug Administration and of the Bureau of Plant Industry in experiments on possible methods of residue removal. These experiments include spraying solvents on the fruit on the vines, as well as washing the grapes after harvest. This work has not reached the point where a practical method of removal can be recommended to the growers.

JAPANESE AND ASIATIC BEETLES

The reorganization, during the year, of the Japanese and Asiatic beetle work and the appointment of C. H. Hadley to its leadership by transfer from the Plant Quarantine and Control Administration have been mentioned. Shortly after the appointment of Mr. Hadley, the activities relating to these insects were grouped into the following sections:

Field supervision.—This unit includes the office of the division leader and is concerned with general administrative supervision over both investigational and business activities.

Maintenance.—The work falling under this unit is concerned with the general maintenance and upkeep of the physical plant, including buildings, grounds, and automotive and other equipment.

Biological investigations.—The activities included under this unit deal with the investigations of the insects and include not only studies on the life history and habits of the beetles but investigations on their movements, relative abundance, and activities.

Control investigations.—This unit deals with investigations to determine artificial methods of controlling or eradicating the Japanese and Asiastic beetles in any stage of their development. It includes the work on insecticides, attractants, and traps or other mechanical devices used in control of either the adult or immature stages.

Parasite investigations.—This unit deals with investigations in control of the Japanese and Asiatic beetles by natural enemies. Its activities include the introduction, colonization, and distribution of parasites from foreign countries; studies of native parasites or predators which attack these beetles; and investigations into the habits and development of the various natural enemies.

The investigations on the Japanese beetle were, as heretofore, conducted in cooperation with the Plant Quarantine and Control Administration. Close and friendly, although informal, cooperation has been continued with the New Jersey Agricultural Experiment Station and the New Jersey Department of Agriculture, as well as

with the Pennsylvania Department of Agriculture. On September 1, 1930, however, the financial aid for investigational work previously extended by the State of New Jersey was withdrawn.

JAPANESE BEETLE

BEETLE POPULATION IN THE OLDER INFESTED AREAS

The opinion, previously reported, that the Japanese-beetle population was no longer at its maximum in the sections of earliest infestations and that it was greater in more recently infested areas, received additional confirmation from the observations made during the season. The areas of present maximum infestation are located in sections on the margin of the general area in which the beetle was originally found and which was the first region to become heavily infested. The areas within which the Japanese beetles were sufficiently abundant to be generally injurious extended outward in New Jersey to such localities as Penningtown, Imlaystown, Browns Mills, New Lisbon, Hammonton, Malaga, and Pedricktown, while in Pennsylvania it extended as far as Lansdale, Valley Forge, Wayne, Media, and Chester. In the pine barrens district of New Jersey there was, however, apparently a decrease in population as compared with those of the seasons of 1927 and 1928. This decrease may be attributed to the recent dry summer in a section where the soil consists largely of coarse sand and gravel. Heavy localized infestations in the pine barrens were, however, observed at isolated points such as Cassville, Lakehurst, Bamber, Green Bank, and Bluebell, N. J.

Density in population of the beetle increased more slowly in high and hilly country than in the more level, low-lying sections. The northward extension of the area in which the beetle population is sufficiently dense to cause the area to be considered continuously occupied was more marked in New Jersey in a belt of low country extending diagonally northeast in the vicinity of Trenton and Hightstown toward Raritan Bay, and less general in the more elevated portions of the State lying above the fall line. The area in which the population is so dense that the area may be considered continuously occupied spread southward in New Jersey to the shores of Delaware Bay. In Pennsylvania the density of population increased more pronouncedly than in previous years, and the area of essentially continuous infestation was extended westward to West Chester, Downington, and Phoenixville and northward to the vicinity of Perkasie. However, throughout the heavily infested area where the density of population has become more or less stationary, soil infestation was substantially the same as in previous years.

EFFECT OF CLIMATIC FACTORS ON THE LIFE AND SEASONAL HISTORY OF THE JAPANESE BEETLE

Both the summer and fall of 1930 were unusually warm and dry, so that in favorable localities by far the greater proportion of the larvæ reached the last instar before cold weather. During the following spring an exceptionally small number of second-instar larvæ were encountered. The appearance of pupæ in the field in the spring of 1931 and the emergence of adults occurred almost precisely at the same date as in the preceding year.

Observations during the year indicate that a soil temperature of 50° F. is the threshold of larval activity, as there is a distinct correlation between this temperature and the periodical vertical movements of the larvæ within the soil.

The life and development of the egg and younger larval stages depend, at least to a large extent, on available soil moisture. Soil conditions at the time of oviposition and immediately following appear, therefore, to have a decided effect on relative abundance of grubs during the following season. During the summer of 1930 there was ample rainfall in June and July in the vicinity of Moorestown, N. J. The drought came later in the summer, at a time when the greater part of the larvæ had reached a stage where they were not so dependent on moisture. In the general vicinity of Moorestown moisture conditions at the critical stage of development were less favorable in 1929 than in 1930, with the result that the beetle population during the summer of 1930 was affected by unfavorable weather conditions to a greater degree than in the season of 1931. The exceptionally severe drought conditions during the summer of 1930 in the territory south and west of Philadelphia occurred, however, at a critical time in the development of the beetle and served to reduce the beetle population in this area during the summer of 1931.

Experiments conducted during the summer and fall indicate that the beetle eggs do not hatch at a temperature of 50° F. or below. Development within the egg does not start even at 54° F., but if the egg has been under favorable higher temperatures it will continue to develop and hatch at this temperature. These studies suggest that under field conditions in the generally infested area eggs will not hatch later than October 15 and that they will not survive the winter temperatures experienced even in southern New Jersey.

Cold and dryness are the two chief physical factors inhibiting spread and establishment of the beetle. Japanese-beetle larvæ are unable to stand any prolonged low temperatures below 10° F. Prolonged drought or unusually dry conditions at the time of oviposition and shortly thereafter are likewise inimical to the development of the beetle. Consideration of these and other facts suggests that the Japanese beetle would find highly favorable conditions for colonization in that section of the Atlantic coast extending from the vicinity of Portland, Me., southward to the vicinity of Wilmington, N. C., as well as in that portion of the country extending inland to the shores of Lakes Ontario, Erie, and Michigan, and southward through Ohio and western Kentucky to southern Virginia and western North Carolina. It is also fairly probable that the beetle will find a number of locations favorable for development at least as far westward as eastern Nebraska, Kansas, Oklahoma, and Texas, as well as in areas along the Gulf of Mexico.

LARVAL INSECTICIDES

Observations on approximately 750,000 evergreen and deciduous plants growing in plats in commercial nurseries in soil treated with acid lead arsenate indicate the wide variety of nursery stock that can be grown under these conditions. Among the plants which are growing successfully in treated soil are species of Abies, Acer,

Andromeda, Azalea, Berberis, Buxus, Cedrus, Chamaecyparis, Cryptomeria, Enkianthus, Euonymus, Ilex, Juniperus, Ligustrum, Leucothoe, Magnolia, Mahonia, Pieris, Picea, Pinus, Pseudotsuga, Rhododendron, Taxus, Thuja, Tsuga, and Viburnum. Certain kinds of nursery plants, including some species of Hydrangea, however, do not grow satisfactorily in soil treated with lead arsenate.

Investigations conducted with acid lead arsenate in cultivated soils show that the insecticidal action of this material is most effective when applied to the soil early in summer before the eggs hatch. The period over which this treatment is effective varies considerably, depending largely on the nature of the soil and the cultural practices.

The treatment of turf with acid lead arsenate continues to be the best method of controlling the larvæ of the Japanese beetle there. In view of the general use of this method, extensive investigation is being carried on with the object of obtaining further information on the different procedures of application, the use of fertilizers, the penetration and persistence of lead arsenate in sod land under different conditions, and the relative effectiveness of the treatment in different localities. A larval survey of the campus at Beaver College, Grey Towers, Glenside, Pa., where traps were run in conjunction with poisoned turf, shows that the average number of larvæ in the lead-arsenate-treated area was 2 to a square foot, while the average for the untreated area in that region was 20 to a square foot. In regions of heavy infestation the treated grass is generally darker and more vigorous than that in untreated areas.

Experiments designed to determine whether other stomach poisons would be effective insecticides in the soil were carried on during the summer. The main object of these experiments was to find a material which could be used around the roots of those varieties of plants which are sensitive to lead arsenate. It has been found that the borates are generally too toxic to be used in soil about the roots of nursery plants. The fluosilicates of barium, magnesium, potassium, and sodium are effective when freshly applied, although much slower in action than acid lead arsenate, but lose their insecticidal value after being in the soil for one year. Calcium fluosilicate has no value as a soil insecticide. The insecticidal action of the arsenates was only slightly lessened after being in soil for one year. Of the arsenates, aluminum arsenate, barium arsenate, dicalcium arsenate, tricalcium arsenate, iron arsenate, acid lead arsenate, magnesium arsenate, manganese arsenate, and zinc arsenate were found to be almost equally effective. The basic lead arsenate proved to be of little value in this connection.

In further experimentation with naphthalene as a fumigant for potting soil, it has been found that, unless the soil is held for several days after treatment to permit the chemical to disappear, the plants put into it are liable to severe injury.

In an effort to locate materials which could be used as dips or washes for nursery stock to destroy the immature stages of the beetle, tests have been made to determine the insecticidal value of emulsions of 110 liquid organic compounds, including alcohols, aldehydes, amines, hydrocarbons, nitriles, nitrates, halogens, sulphur compounds, and esters. The results with third-instar larvæ show that the most toxic dips contained allyl bromide, benzyl bromide,

chloroacetone, allyl isothiocyanate, ethyl isothiocyanate, methyl thiocyanate, methyl-alpha-naphthylamine, ethylnaphthylamine, or beta-beta-dichloroethyl carbonate.

INSECTICIDES FOR THE ADULT BEETLES

Extensive experiments were conducted with ethylene oxide as a fumigant to destroy adult Japanese beetles which might be present in boxes of raspberries, blackberries, or blueberries when the fruit is ready for shipment. It was found that fumigating fruit with ethylene oxide at the rate of 2 pounds per 1,000 cubic feet of space for two hours, with the temperature 75° F. or above, would destroy any adult Japanese beetles among the berries without causing any injury of commercial importance to the fruit. At 75° ethylene oxide is a gas and becomes immediately available as an insecticide. It has the advantage over carbon disulphide that the fire hazard is practically eliminated and no special vaporizing apparatus is required.

Tests were conducted to determine the relative effectiveness of different commercial forms of cyanides against the adult beetles in cars loaded with bananas. All types of materials tested were found to be effective and dosages and length of exposure have been determined. Under laboratory or control conditions it was found possible to fumigate wet and dry bananas without injury to the fruit, by holding it at a temperature of 75° F. for one hour. Only very small quantities of cyanide were absorbed by the fruit and the treatment did not impair its appearance or flavor, although holding it at the effective temperature hastened ripening to some extent.

CONTROL BY MECHANICAL MEANS

Tests were made to determine the value of mulch paper in preventing injury about nursery plants. From these tests it would appear that such means would reduce, but not eliminate, oviposition in the covered soil.

Investigations on traps were continued with the object of increasing their effectiveness. Observations during the season indicate that traps with white baffles and white funnels are more effective than traps with green baffles and green funnels. The present standard trap is more efficient without the ventilating system. Small traps are more effective, on the cost basis, than larger ones. From the season's observations it would appear that traps will decrease the number of beetles in an area but will not in themselves afford protection to the plants. When used in conjunction with the soil treatments the beetle population is, however, very greatly reduced.

WORK WITH PARASITES IN FOREIGN COUNTRIES

Work on foreign parasites has been continued in Japan, and during the year shipments of the following parasites were received from that country:

Tiphia vernalis Roh	12,678 adults (about 90 per cent arrived alive).
Tiphia ascricae A. and J	11,258 cocoons.
Tiphia popilliavora Roh. (Korean)	335 cocoons.
Dexia ventralis Ald	20,500 parasitized *P. japonica* larvae.
Centerter cinerea Ald	10,000 approximately.
Prosena siberita Fab	900 parasitized *P. japonica* larvae.

Rather extensive scouting was carried on in Japan in areas which heretofore have not been examined, and one new parasite was discovered.

Explorations for possible parasites were also carried on in Australia, but as yet no promising parasite of the Japanese beetle has been located. Considerable information has, however, been obtained on the habits of *Ithone fusca* Newm., a species which has been recorded as predacious on scarabaeid beetles.

ESTABLISHED INTRODUCED PARASITES

Five species of parasites of the Japanese beetle, which have been introduced from time to time, have become established within the area infested. Three of these are flies, and none of them has yet been able to reproduce in sufficient quantities to be of any importance in reducing beetle populations. The other two are fossorial wasps and have already demonstrated their usefulness in limited areas.

Colonies of the fly parasite *Centeter cinerea* Ald. have been established at points within an area covering approximately 1,500 square miles. The natural spread of this species has been limited, and its distribution into outlying areas has been augmented by the liberation of colonies. The mean annual temperature of the Philadelphia region is from 7 to 10 degrees higher than the areas in Japan where this parasite is most abundant. This warmer temperature seems to cause the parasite to emerge two or three weeks in advance of its host. For this reason it is not expected that this parasite will be of economic importance in the present heavily infested area. The work on *C. cinerea* is to be discontinued until its host becomes abundant in climatic regions where the life history of the parasite synchronizes with that of its host.

During the summer of 1930 recoveries of the fly parasite *Prosena siberita* Fab. indicated a natural spread of approximately 1 mile from a center point of liberation, but the numerical increase of the species was limited. No recoveries were made, however, in areas where the species had been colonized in previous years. Climatic conditions within the area now generally infested by the Japanese beetle are apparently unfavorable for the rapid propagation of this species. Attempts made during the summer to reproduce it in insectaries and in field plats have not been very encouraging. It is therefore planned to discontinue work on this parasite at least for the time being. Preliminary studies to determine whether *Prosena siberita* would feed on the Asiatic beetle (*Anomala orientalis* Waterh.) or the Asiatic garden beetle (*Aserica castanea* Arrow) gave negative results for the Asiatic beetle but 14 per cent parasitism for the Asiatic garden beetle. Strangely enough, when the Asiatic garden beetle served as its host, a generation of the parasite was completed in 47 days, although under ordinary conditions there is only one generation a year.

The only colony of the parasite *Dexia ventralis* Ald. which has been established is located in the vicinity of Haddonfield, N. J. The species seems to have died out at all other colony centers. During the summer of 1930 somewhat more than 3,500 adults of this parasite were liberated in eight new areas within the vicinity of Chestnut Hill, Pa., where both the Japanese beetle and the Asiatic garden

beetle are abundant. It was hoped that the prevalence of grubs of these two species, both of which it successfully attacks, would aid in its establishment, but scouting during the following May and June gave only negative results. Studies on the habits of Dexia have shown that this species can be successfully reared on six species of scarabæoid larvæ, both native and introduced, which occur within this region. Because of its apparent inability to reproduce sufficiently to be of economic importance, foreign shipments of this species have been discontinued and the studies on its habits conducted in this country will be curtailed until the population of the Japanese beetle becomes abundant in climatic zones more favorable for the establishment of Dexia.

The localities of the 12 initial liberations of the wasp parasite *Tiphia vernalis* Roh. were scouted during 1930, and parasites were recovered in 6 of the areas involved. Extensive recoveries were made at Philmont, Pa., where the species is well established and rapidly increasing and spreading. Ten per cent of the grubs examined from this area were parasitized. During the summer of 1930, 7 new colony centers were started, 4 of these in Pennsylvania, 2 in New Jersey, and 1 in Long Island.

The three areas in which the original colonies of the wasp parasite *Tiphia popilliavora* Roh. were liberated in 1921 and 1922 are now united and cover about 4 square miles in the vicinity of Riverton, N. J., This area has been used as a source of supply for new colonies since 1927. During 1929, 1,000 females were taken from this center for liberation and a total of 147 colonies of this species have now been placed in the field. During August, 1930, the initial colony showed such depletion that large-scale collections were postponed. This depletion is considered to have been caused by the extensive collections and to the drought of 1929, which was detrimental to both host and parasite. During the summer it was possible to examine only 50 of the localities where colonies of *Tiphia popilliavora* have been liberated. Recoveries were made from 24 of these centers. The number of individuals in the colonies differed considerably. In 12 they were numerous and the colonies were fairly strong, one at Columbus, N. J., covering an area of half a square mile.

ASIATIC BEETLE

The dry weather during the summers of 1929 and 1930 caused a reduction in the numbers of Asiatic beetles (*Anomala orientalis* Waterh.). The season of 1931 was much more favorable, however, and the species is becoming increasingly abundant in all the areas in which it has become established. The Asiatic beetle overwinters as a grub deep in the sod land, moves upward in April, and feeds a short time before pupation. The period of adult emergence was substantially the same in 1930 as in 1929. The adult was present from about the middle of June to about the middle of August, being most abundant during the first week in July. During 1930 oviposition was first observed on July 2, and the greatest numbers of eggs were laid between July 18 and 30. During this 12-day period as many as 56 eggs per square foot were found at Jericho, N. Y. Later, because of dry conditions, the grubs became very scarce. The ground was so dry that eggs shriveled up and grubs either died or their

development was greatly retarded. Because the mild autumn permitted feeding over a longer period, those grubs which survived these conditions entered the winter about normal in size. When forced into hibernation in November, about 65 per cent of the grubs examined in Long Island were in the third instar, the remainder in the second. Not more than 90 per cent of these grubs complete their development in one year. The remainder become fully fed in late July or early August but do not complete their development until June of the following year. The grub of the Asiatic beetle is very active and, in addition to considerable vertical seasonal migration, there is apparently considerable lateral movement within the soil.

Prior to 1930 no injury by this beetle had been found elsewhere than in well-kept lawns. In 1930 grub injury was reported from gardens that had been under cultivation for a number of years. In some cases grubs had fed extensively on the roots of strawberries, corn, and raspberries.

ASIATIC GARDEN BEETLE

The drought of the summers of 1929 and 1930 also reduced the numbers of the Asiatic garden beetle (*Aserica castanea* Arrow), although the dry weather apparently affected this species less than it did the Asiatic beetle. This is apparently because of a difference in habits, as the Asiatic garden beetle flies largely at night and seeks moist places in which to find concealment from light. Oviposition apparently occurs largely in such places. Grubs of this beetle winter in sod lands at depths ranging from 8 to 17 inches and migrate to the surface for spring feeding about the middle of April. During 1930 about 70 per cent of the grubs found in April were in the third instar and the remainder in the second. They changed to pupæ about the last part of June or the first half of July. The first adult was noted two weeks later than the first had been found the previous year. Eggs were found in the field from July 3 to October 30, but they were more numerous between July 25 and August 10. In the spring of 1931 the grubs were much more abundant than they had been in previous years and adults were present after the middle of April. In the summer of 1931 the insect again increased in numbers and both adults and grubs were more abundant than during the previous two years. The grubs of the Asiatic garden beetle move both laterally and vertically in the soil. In cage tests grubs without food moved 34 inches in nine days while when food was present they traveled 20 to 30 inches in about the same time.

Prior to 1930 the injury caused by the grub of this species had been noticed only in lawns. During the summer of 1930, however, grub injury was reported in cultivated gardens. The larvæ were recorded as feeding on beet, begonia, corn, onion, and strawberry plants, and on nursery seedlings. By the end of September, 1931, grub injury was observed to be more general than in any year since investigations were started in 1927, both on turf and on many plants, including strawberries and young plants of beet, onion, and corn.

The adults of this species are attracted in large numbers to lights. They appear to be active and flying only when the temperature is 70° F. or over. At such times they sometimes fly to considerable heights and have been reported on the roofs of 30-story buildings

in New York City. Experiments with light traps show that the light given by a daylight bulb is much more attractive than that from clear or frosted bulbs. Although the light trap is still in an experimental stage, several owners of estates in the heavily infested area have erected them in an effort to reduce beetle population. Under favorable conditions large numbers of beetles have been collected.

During 1930 approximately 1,500 specimens of the wasp parasite *Tiphia asericae* A. and J. were imported and liberated near Chestnut Hill, Pa. During May of that year parasitized Aserica larvæ were found 10 days later. Other liberations of this parasite were also made during 1930 at Westbury, Long Island. Scouting during May and June of the following year failed to recover any adult parasites in either Pennsylvania or Long Island.

CEREAL AND FORAGE INSECTS

The work on insects affecting cereal and forage crops is under the direction of W. H. Larrimer.

The more important older projects of this division are researches on the European corn borer, the Hessian fly, the corn earworm, the chinch bug, grasshoppers, the alfalfa weevil, and other primary pests of forage and grain crops. Newer projects, or the newer phases of older projects, concern the occurrence of the alfalfa weevil in southern Oregon, the diseaselike injury of alfalfa and other forage legumes caused by leaf hoppers in various sections of the country, the range caterpillar in northeastern New Mexico and the panhandle of Texas, and the control of the Mormon cricket in northwestern Colorado.

EUROPEAN CORN BORER

The necessity of preparing this report in midseason confines it, for the most part, to a summarization of the first half of the fiscal year, namely, the latter half of the season of 1930. The essential information on the season of 1931, including spread and population increase, includes data which can only be obtained subsequent to this report, much of it in the late summer and fall of the current year. The exceptional drought of the summer of 1930 affected the spread of the corn borer westward and southward and also reduced its numbers in the old areas of infestation. There was very little apparent spread of this insect westward. In Indiana the boundary of infestation remained practically as reported for 1929. In Ohio there was a slight extension southward into Clermont, Adams, and Pike Counties bordering on the Ohio River. Small extensions of this area project across the river into Bracken and Lewis Counties, Ky. There also occurred a southeasterly advance of about 10 miles along the Ohio River Valley into West Virginia. Elsewhere the spread of the corn borer in 1930 was almost negligible. Practically no commercial damage occurred during this year.

The surveys in the fall of 1930 indicated a reduction in numbers of the insect ranging from 20 per cent in Michigan to about 60 per cent in Ohio, with intermediate reductions in Pennsylvania and Ohio. These reductions were largely due to the death of eggs and

young larvæ when exposed to the sun by the wilting of the corn leaves.

The drought also caused the very young caterpillars to attack the ears of corn without feeding externally on the leaves. They sought the shelter of the crevices between leaf and stem immediately after hatching. A marked early migration to the lower portions of the stalk was later observed. Another remarkable effect of high temperatures with absence of moisture was the appearance of a few second-generation pupæ in this normally 1-generation area in Erie and Henry Counties, Ohio.

The spring surveys of 1931 indicate that existing infestation in the Great Lakes region is sufficient to cause serious trouble should the summer of 1931 prove unusually favorable to the insect. It was observed that there was considerably more corn débris remaining on the surface of the soil this spring than has been the case for several years past, and this condition is favorable to corn-borer survival and increase. In July high temperatures and abundant moisture prevailed in the region of the Great Lakes at the peak of the period of moth emergence and oviposition—conditions that are likely to bring increased infestation.

Progress in introduction of parasitic enemies of the corn borer has been excellent during 1930–31. About 750,000 of these parasites were liberated in various parts of the infested area. Extensive collections of corn-borer larvæ in such areas have shown that some of these introduced species are now destroying from 6 to 16 per cent of the borers present. To date there have been liberated a total of more than 2,500,000 of these parasites, comprising 19 species, of which 12 are known to have become established. Four of these were found during the year to be newly established in the region of the Great Lakes. Several important technical publications giving results of biological studies of some of these parasites were issued during the year.

The work on the cosmopolitan parasite *Trichogramma minutum* Riley was discontinued at the beginning of 1931, as it was found that the liberation of laboratory-bred material was inefficient owing to weather hazards, small area of dispersion, and lack of alternate hosts in much of the area under experimentation.

SOUTHWESTERN CORN BORER

The southwestern corn borer (*Diatraea grandiosella* Dyar) is believed to have entered the country from Mexico, and has become of major importance to corn culture in the Southwest. It was found to have extended its range from western Texas and New Mexico into the panhandle of Oklahoma. The indications are that eventually it will enter southern Kansas and that it may become an important pest of corn in the Mississippi Basin. Studies of the biology and control of the insect have been under way for several years.

RANGE CATERPILLAR

Although the cold, dry winter of 1929–30 killed nearly 50 per cent of the eggs of the range caterpillar, the stage in which it overwinters, no perceptible decrease in the number of caterpillars was

observed in northeastern New Mexico in the summer of 1930. This pest usually is held under control by a specific native egg parasite, *Anastatus semiflavidus* Gahan, but at present this parasite has become much reduced in numbers. The result has been a widespread and serious outbreak of the range caterpillar, which has devoured the grass on much of the finest cattle range in the areas affected. The efforts of the bureau investigators during the past year have been directed chiefly toward the artificial multiplication of the controlling parasite. These efforts have been quite successful and in May, 1931, about 2,000,000 parasites of this species were liberated in the most heavily infested sections of the range country. It is planned to continue this work during the ensuing year.

ARMY WORM

During June, 1931, several outbreaks of the army worm occurred in the eastern half of the Mississippi Basin, and investigators of the bureau gave effective aid in Posey County, Ind., and Shelby County, Ky. The poisoned bait applied at their suggestion was very successful. A radio broadcast giving information on control was released through a Louisville broadcasting station immediately after the outbreak was reported to the Department of Agriculture.

GRASSHOPPERS

Following immediately upon two or three years which were favorable for grasshopper multiplication, very serious grasshopper outbreaks began to develop in various part of the western Mississippi Valley early in the spring of 1931. The grasshoppers were local species and the damage was in no instance the result of migrations from the western plains sloping from the Rocky Mountains, as was the case in the great grasshopper scourges of the seventies and eighties; in fact, the species involved in those early outbreaks, known as the Rocky Mountain locust, seems to have practically disappeared. The grasshoppers responsible for the outbreaks of this year were chiefly the 2-striped grasshopper and the differential grasshopper. Neither of these species is a migratory insect in the true sense, for both are rather heavy bodied and capable of only short flights.

The probability of heavy grasshopper outbreaks in the season of 1931 was recognized by the entomologists of the bureau, and predictions of such outbreaks were made in 1930; but, probably because of the economic situation, which had very seriously affected the income and resources of farmers of this district, very little preparation to meet the menace was made in advance. As a result, the damage was well under way and practically out of control before any very active work to limit losses was done. While more or less general damage and occasional heavy local injury occurred throughout the area, the most widespread and radical damage occurred in an area, 100 miles or more in extent, divided between southern South Dakota and northern Nebraska. Attempts to poison the grasshoppers in this and other areas were more or less futile because of a late start and in part because of the receipt and distribution of a commercial brand of poisoned bait which contained only half the

required strength of arsenic. In general, the damage by the grasshoppers was little checked by such efforts.

The outlook in July, 1931, is that, with winter conditions favorable to the grasshopper, there is strong probability of a repetition of extensive grasshopper damage in 1932. To meet this situation the bureau is planning to cooperate with the State and local agencies in surveys this fall and winter to locate the areas in which eggs have been abundantly deposited, so that such areas can be cultivated by their owners or otherwise treated in such a manner as to expose the eggs to the killing action of winter. The bureau also plans to cooperate in preparing a program for poisoning the young hoppers early next season. No funds are available to give direct aid in such operations, but the forces of the bureau concerned in grasshopper investigations will be detailed to render all possible aid in making surveys and outlining and preparing control operations.

In response to many demands for aid during the outbreak of the current season, in the absence of funds for the purchase of poison, for labor, or for other direct assistance of this nature, the bureau devoted its available personnel to cooperation with the States and local agencies in advice and direction of such control efforts as were instituted very largely by the owners themselves or through the support of State or local funds.

ALFALFA WEEVIL

Surveys under way in July, 1931, indicate that the new infestation of the alfalfa weevil reported in the vicinity of Medford, Oreg., in the summer of 1930 has not spread materially during the past 12 months. In eastern Oregon, especially in Baker and Malheur Counties, the infestation, which formerly had been quite serious, was found to have diminished, and it was difficult for even the experts to find specimens of the insect. During 1930 a new infestation was discovered in Teton County, Idaho, and extensions of infestation in Colorado were observed but no new counties were invaded. In the older areas of infestation in Utah, a high percentage of parasitism by *Bathyplectes curculionis* Thoms., a species introduced from Europe by this bureau, was found to prevail. At the beginning of July, 1931, the damage from the alfalfa weevil in 1931, except in western Nevada and northern Utah, promises to be almost negligible.

SUGARCANE BORER

The sugarcane borer continues to be one of the principal limiting factors in the production of sugarcane in the Gulf States. Efforts toward control have been concentrated during the year in the introduction from South America of the insect parasites of this pest. Two species of parasitic enemies are being brought from Peru to New Orleans and liberated in large numbers. During 1930 about 180,000 specimens were introduced and in the spring of 1931 an additional 140,000 were received and liberated. Recently it has been found possible to transport these beneficial insects by airplane from Trujillo, Peru, direct to Miami, Fla., where, through cooperation with the Plant Quarantine and Control Administration, they are transshipped by train to New Orleans. By this procedure it was possible

to liberate the parasites on the sixth day after they left Peru, whereas formerly 22 days were required for this journey. This is believed to be the first time in history that parasitic enemies of insects have been transported by airplane from a foreign country to the United States.

BILLBUGS

For several years a comprehensive study of the billbugs injurious to cereal and forage crops has been under way at Webster Groves, Mo. The partial results of these studies have already appeared in a farmers' bulletin giving methods of control for most of the injurious species. This has been supplemented during the past year by the publication, in Annals of the Entomological Society of America, of an illustrated synoptic key to the known pupæ of the billbug genus Calendra, which renders it possible for the entomologist, without actually rearing the adult, to determine what species is under observation.

RED HARVESTER ANT

Although agriculture in the United States is not nearly so badly afflicted with herbivorous ants as is the case in many tropical countries, a few such species cause much annoyance and loss in the southwestern part of this country. Among these pests is the red harvester ant, found from south-central Texas westward to California. It denudes the surface of the soil in the immediate vicinity of its nests in cultivated and uncultivated fields, sometimes causing numerous bare areas each of which may be as much as 25 feet in diameter. It provisions its nest with the seeds of alfalfa and related plants, often removing a large portion of the crop in this way; and as it stings severely, this species can be considered a first-class pest. Studies of this ant have been in progress for several years, and as a result a farmers' bulletin giving satisfactory methods of control (the most effective being the use of carbon disulphide and London purple), as well as much other pertinent information, is in press.

CORN LEAF APHID

In the early years of its history the corn leaf aphid (*Aphis maidis* Fitch) was confused in the literature with a closely related species now known as the corn root aphid (*Anuraphis maidiradicis* Forbes). The biology of the corn-leaf form was obscure and little understood by entomologists, but as a result of studies pursued in the Southwestern States by bureau specialists most of the facts relating to the life processes of this pest have become known and are embodied in a manuscript recently submitted for publication through departmental channels.

SOD WEBWORMS

The studies of the principal economic species of sod webworms, carried on for many years in this division, were suspended on December 20, 1930, by the death of G. G. Ainslie, who was in charge of these investigations. During his service Mr. Ainslie's contributions to the knowledge of these important pests were many and valuable.

They consisted of a farmers' bulletin giving general control methods, and several technical publications detailing the biology and ecology of the more injurious species. His last contribution appeared as Technical Bulletin 173, The Bluegrass Webworm, published in February, 1930.

HESSIAN FLY

For many years it has been suspected that under some conditions the Hessian fly may exist indefinitely in native or other grasses. Conclusive experimental evidence to support this belief has, however, been lacking. The question has an important bearing on the control of the pest because, if the insect is always present in any numbers in wild host plants, regardless of the presence of the small grains, such host plants should be considered in planning any thorough scheme of control. To settle this point two bureau investigators, working independently in Indiana and Oregon, respectively, reared numerous individuals from wheat and then bred them into wild grasses; they then bred the progeny of such specimens back into wheat and produced fertile offspring. The results of one of these experiments have recently been published in the Journal of Agricultural Research.

As the seasonal history of the Hessian fly in the Pacific Northwest has been found to be quite different from that prevailing in the region east of the Rocky Mountains, particularly as to number and time of appearance of the generations, a publication treating on the biology of the insect in this region has been prepared and will appear through departmental channels.

LEAF HOPPERS AND ALFALFA

Excellent progress has been made in determining the character of the injury done to alfalfa and other legumes by leaf hoppers. It was originally believed that the insects acted as vectors of a specific disease that caused the condition commonly known as alfalfa yellows. The work done during the year, however, indicates that this condition results principally, if not entirely, from mechanical injury by the insects and loss of sap from their feeding. The species of plant hoppers chiefly responsible for these injuries have been determined and an investigation has been begun to ascertain whether certain varieties of legumes are resistant to the action of the insects, and, if so, why. Several technical publications detailing these results have been issued.

TRUCK CROP INSECTS

Investigations of vegetable and truck crop insects have been continued during the fiscal year under the general direction of J. E. Graf [1] and W. H. White.

BEAN INSECTS

MEXICAN BEAN BEETLE

In 1930 damage to the bean crop in the Eastern States by the Mexican bean beetle was checked by the abnormal season. The prolonged drought and high temperatures which prevailed depleted the popula-

[1] Resigned on Mar. 4, 1931.

tion of the beetle over the greater part of the affected area to such an extent that the use of control measures was limited. Although in general the percentage of beetles which survived the winter of 1930–31 was the highest on record, fewer beetles had entered hibernation in the fall of 1930 than in previous years. In 1931, consequently, the bean crop was little damaged by the first generation of beetles except in New Jersey, eastern Tennessee, and northern Alabama.

Less new territory was invaded in 1930 than in any other year since the appearance of the beetle in the East in 1920, the only appreciable spread being to the northeast in the New England States, where the beetle reached the central portion of Massachusetts.

Additional shipments of the parasite *Paradexodes epilachnae* Ald., a tachinid fly, were received from Mexico at the Columbus, Ohio, laboratory. From this material a large number of the adult flies were reared, and during the fall puparia of the fly were stored under various conditions, but none passed the winter successfully. This failure was anticipated because of previous experience, so an attempt was made to breed the parasite in the greenhouse throughout the winter. This was successfully accomplished and provided a stock of parasites, from which large numbers have been reared. It is planned to make liberations at several points in the infested area in the East and Southwest. Since the bean beetle belongs to the same insect family as beneficial lady beetles, tests have been made with the larvæ of seven species of native lady beetles to determine whether the parasite will attack beneficial species. Repeated trials, have demonstrated that the common lady beetles are not subject to parasitism by this tachinid, consequently it is believed that this parasite can be liberated without danger of its preying upon the beneficial species.

Extensive tests were conducted with fluorine compounds, principally barium fluosilicate, cryolite, and potassium fluoaluminate, but owing to the condition of the foliage throughout the greater part of the season no conclusive results as to the effect of these chemicals on bean foliage were obtained. The indications are that, when used in a dust form, these materials will not give such satisfactory control of the bean beetle as does magnesium arsenate or calcium arsenate, because they do not adhere to the foliage so well as do arsenical dusts.

A special study was made in cooperation with the Bureau of Chemistry and Soils to determine why some brands of calcium arsenate are more injurious to bean foliage than others. Chemical analysis did not reveal any factor that was directly responsible for toxic action of calcium arsenate on the bean foliage. Extensive tests in the laboratory, where bean plants were treated with calcium arsenate and held under different atmospheric conditions, show, however, that there is a direct relation between low atmospheric evaporation and injury to bean foliage from calcium arsenate. Temperature does not appear to be an important factor.

Various materials have been used in combination with calcium arsenate in an attempt to discover some means of rendering this chemical less toxic to bean foliage. Calcium sulphide proved to be a good corrective, but it was difficult to keep the combination in suspension. Copper-lime dust and sulphur are useful in this connection.

Experiments in commercial control, which have been conducted on the Eastern Shore of Maryland during the last two years, were reduced to a minimum as a result of the drought.

Since the bean beetle has increased in abundance in the Southwest during the last two years, particular attention has been directed to large-scale control experiments. The results show that calcium arsenate is the only practical remedy for use in the dry-farmed area of the Southwest, the chemical being comparatively inexpensive and its physical properties superior to those of the other commercial poisons. Because of the lack of atmospheric moisture in this area plant injury from calcium arsenate is not serious.

This season's studies on the hibernation and relative abundance of the beetle in the fields in this area confirm the results of the preceding six years' work, showing that rainfall stimulates and temperatures above 50° F. accelerate emergence of the beetle from hibernation. Permanent emergence rarely occurs when the daily temperature is below 50°. With information of this character at hand, the time of the initial infestation and the intensity of infestation in the fields can be determined—a very important factor from the control standpoint.

LIMA-BEAN POD BORER

A study of the Lima-bean pod borer (*Etiella schisticolor* Zeller) was initiated at Ventura, Calif., in August, 1930. The results thus far indicate that there is a possibility of controlling this insect with insecticides, since laboratory observations of the activities of the larva show that it moves about considerably over the bean plant before entering the pod and that after entering the pod it consumes pod tissue.

SWEETPOTATO WEEVIL

The cooperative control work on the sweetpotato weevil in southern Mississippi and Alabama during the year has yielded encouraging results. Further progress has been made in reducing the number of infested farms in Mississippi and also the intensity of infestations. The heaviest infestation reported in the 1930 crop was 2 per cent, and most of the reports showed less than 1 per cent. Not one infested farm has been found in Baldwin County, Ala., and the infested properties in Mobile County have been reduced from the original 114 to 1. It is reasonable to expect that this infestation will be wiped out in another season. Assistance has been extended to the States of Louisiana and Texas through the services of the leader of the project.

A motion-picture film showing the nature of the damage by the sweetpotato weevil and the measures which are taken to keep it under control is in preparation, and it is believed that this film will be of great value to the grower of sweetpotatoes.

WIREWORMS

Wireworm investigations have been continued in the West and South, a new laboratory having been established during the year at Fairfax, S. C., to undertake a study of the sand wireworms.

Although extensive experiments have been conducted in the West on the direct and indirect control of wireworms, no satisfactory remedy has yet been developed. These experiments, undertaken in cooperation with the Bureau of Agricultural Engineering, included the use of mechanical means such as steam sterilization and rotary plows. Tests with baits which involved the use of a large number of different types of poisons failed to yield satisfactory results. The poisons were mixed with whole-wheat flour, this material having proved to be attractive to wireworms, and the mixture was formed into balls.

Carbon disulphide is an effective soil fumigant against wireworms. The cost of treatment with this chemical, together with the absence of a ready means of application, limits its use. Lands properly treated with carbon disulphide will be free from damaging infestations for at least three seasons. This season's experiments have shown that carbon disulphide placed in 1-ounce dosages 4 inches deep and 24 inches apart will penetrate the soil and kill wireworms to a depth of 18 inches. This is especially true in sandy-loam soils when the moisture content is between 10 and 20 per cent. In the heavier clay-loam soils the wireworms are killed only in the top layer above the plow line. In a series of laboratory experiments, in which wireworms were placed in an atmosphere saturated with paradichlorobenzene and naphthalene, from five to six and one-half hours' exposure to paradichlorobenzene was required to kill 50 per cent of the worms, and with naphthalene eight hours was required to kill 40 per cent of the worms.

A large number of chemicals have been tried as attractants to the adult beetles. The outstanding result of these experiments was that caproic acid and butyric acid were attractive to the adult males of the species *Limonius canus* Lec. In a trap containing caproic acid 2,745 males and only 148 females were captured; in a trap baited with butyric acid 1,506 males and 145 females were taken.

In hibernation studies of the larvæ and adults it was shown that 94 per cent of the larvæ hibernated at a depth of 3 to 12 inches, 63 per cent of this number being found at a depth of 6 to 9 inches. Ninety-nine per cent of the adults were found at a depth of 3 to 9 inches, 54 per cent of this number being at a depth of 6 to 9 inches.

Additional studies have been made on the effect on the larvæ of submergence in water. These experiments bring out the fact that wireworms, both young and nearly grown, can withstand long periods of submergence without any apparent ill effects. Therefore flooding in irrigated sections would not be a practical means of reducing wireworm infestations.

Wireworm infestations seem to decrease, or at least do not build up so fast, in lands planted to alfalfa as in lands tilled throughout the season. Records taken on wireworm populations in land planted in alfalfa for four years show that this land has only one-half the number of wireworms as other fields planted continuously in truck crops. A large series of crop-rotation experiments to determine the value of farm practices as a means of checking wireworm damage has been started in Idaho.

In California it has been found that the number of eggs deposited by the females is greater than has hitherto been reported and that

the length of life of the wireworms may be less than three years. The rate of growth and length of life of wireworms are affected by temperature. With abundant food throughout the year, *Limonius californicus* Mann. may complete its development in two years under optimum conditions, whereas under field conditions three years or more are required. In an experiment eggs flooded for 25 days failed to hatch. Seventy-seven per cent of the eggs hatched after 5 days of flooding, 50 per cent after 10 days, and a little over 30 per cent after 20 days. An average of 90 per cent of the eggs that were held as checks hatched.

The study of the sand wireworm has not been in progress long enough to yield any definite results. Crop-rotation experiments, tests of crops for possible resistance to wireworm attack, and studies of the best planting dates as a means of reducing injury are under way.

An interesting result occurred in the experiments with baits. On the plat where 1,000 pounds of cottonseed to the half acre were applied two weeks prior to the planting of corn, the corn developed normally, and the indications are that a fair yield will be obtained. In the check plat, where rye was turned under several weeks before planting, the corn was seriously injured by wireworms. It would appear that there is some relationship between injury from this wireworm and the quantity of humus in the soil.

Wireworms, particularly the species *Heterodercs laurentii* Guer., are becoming of increasing importance to the vegetable industry of the South. Here, as in other sections, crop-rotation studies are being made, as this appears to be the most promising means of reducing injury on large acreages. The early potato crop of the South is particularly susceptible to injury and the principal loss to the grower is due to the lowering of the grade of the potato which bears feeding scars of wireworms.

SEED-CORN MAGGOT

The solution of the seed-corn maggot problem has developed to the point where it is believed that suberization of potato seed pieces prior to planting can be recommended to the grower as a means of reducing losses from this pest. Another season's work has shown quite conclusively that this treatment prevents injury by the seed-corn maggot and also that the commercial potato grower can satisfactorily suberize his seed pieces without much expense or additional time.

This insect is also a pest of seedling spinach on the eastern coastal plain. Experiments in its control as a pest of spinach have indicated definitely that organic fertilizer should not be used at the time of planting. If a fertilizer is necessary, it should not contain any organic matter, as such materials are attractive to the adult fly for egg deposition. Delay in the application of all fertilizers until the plants are past danger of injury from the seed-corn maggot has been adopted with good results by some growers in the Charleston, S. C., district.

The seed-corn maggot is most active in the South during the cooler months of the year. Consequently, the late spinach crop and the early potato crop are particularly subject to injury. Although extensive observations and experiments have been conducted, it has

not been determined in what location or in what stage the insect passes the summer. A few flies may be found throughout the summer months, but their numbers increase very rapidly with a drop of the temperature in the fall.

SPOTTED CUCUMBER BEETLE

Additional data gathered during the past season from a field study of the spotted cucumber beetle strongly indicate that this species breeds scantily in the South during the summer and that very few of those produced survive to account for the large winter population of the insect. There is evidence to show that the winter population in the South consists largely of beetles that emerge in the North during the fall and migrate southward. During 1930 the issuing peak of this fall brood at Muscatine, Iowa, was reached about September 25. Soon after issuing the beetles start southward, feeding on fall-flowering plants during the migration. The migration into Louisiana is completed about December 15, at which period the winter vegetable crops become infested. The beetles breed throughout the winter in the South, and with the approach of spring begin to move northward. Such migration is further indicated by attempts to carry the beetle over the winter in cages at Hartsburg, Mo., Muscatine, Iowa, and Elk River, Minn., which met with failure. In an attempt to trace their movement, more than 40,000 beetles were marked and immediately released. It is indicative that only a few of these were recovered in the fields where they were liberated. Three marked beetles were found about 2 miles south of the point of liberation.

With regard to the control of the pest, it has been observed that the broad bean is very attractive to the insect and therefore might serve as an excellent trap crop upon which the forms migrating in the fall could be killed as they collect. During the emergence period of the spring brood candytuft is a favored food of the males. Barium fluosilicate and potassium hexafluoaluminate have given some promising results as a control but further tests under varying atmospheric conditions are necessary in order to determine the effect of these chemicals on the plant foliage.

BERRY INSECTS

STRAWBERRY WEEVIL

Further biological studies verify observations of the past season on the aestivation and hibernation periods of the strawberry weevil. After emergence from the pupal stage, which takes place during May and June, the adult starts feeding on the blossoms of a variety of plants in or about the strawberry field and continues to feed for 10 days to two weeks. Following this feeding period, the weevil seeks shelter in débris, usually somewhere in the immediate vicinity of the native food plant, to aestivate and hibernate. Apparently aestivation is not induced by a lack of suitable food, but takes place just as soon as sufficient food has been eaten to provide for the long rest period. Food is always abundant at the time the beetles become inactive.

Besides the control by sulphur arsenate dust, the value of winter clean-up of the waste areas immediately adjacent to berry fields as a means of preventing damage by the weevil has been demonstrated to many growers in the Chadbourn, N. C., district during the past season. Where winter quarters were cleaned up, injury to adjoining strawberry fields was slight.

The weevil occurred in unusually damaging numbers in Louisiana during the past season. It also occurred in injurious numbers in Mississippi. The damage in Louisiana was particularly severe, since it came after the crop had begun to bear and consequently calcium arsenate-sulphur mixture was not advocated as a control because of the danger of arsenical residue on the ripening berries.

BERRY MITES

Cyclamen mite.—The cyclamen mite (*Tarsonemus pallidus* Banks)[2] was first recognized as a pest of strawberries in this country in 1928, when it was found in widely scattered plantings in the Northeastern States. It is now generally prevalent and destructive on the west coast, particularly in the Santa Clara Valley of California. Experiments have shown that the use of humid heat may become a satisfactory means of ridding nursery stock of this mite. In some preliminary experiments with an everbearing variety the plants were tied in bundles of 50 and exposed to a temperature of 110° F., temperature records being taken both at the center and at the outside of the bundles. In one test the bundles were exposed for one and one-half hours and in another for three hours. The temperature was reached in the outside of the bundles two hours earlier than in the centers, so the outer portions were heated for two hours longer than the centers. Untreated plants and the treated plants were set out in the field. It was evident some time later that the flower buds on the treated plants were damaged and it was also found that the roots had been seriously injured. In spite of this injury the plants recovered and made an excellent growth. They bore very little early fruit but developed considerable blossom later in the season. These plants were apparently freed of the mite, as the untreated plants showed a decidedly inferior growth and were heavily infested.

Red berry mite.—During the latter part of the season of 1930 the first serious outbreak of the red berry mite (*Eriophyes essigi* Hassan) occurred in the main blackberry-growing districts of Oregon and Washington. A thorough survey of the damage caused by the mite in these States revealed three infested areas, one in southern Oregon, one in the Willamette Valley, and the third between Tacoma and Seattle, Wash. Near Woodbury, Oreg., 95 per cent of the crop was lost in a number of fields. Heavily infested berries did not ripen, and in the case of light infestations the fruit was unsatisfactory for canning because of its color and flavor. Control experiments with lime-sulphur and oil sprays were undertaken during the dormant season, but it is too early to determine the results.

[2] There is some question as to whether the species concerned here is *pallidus* Banks or *fragariae* Zimm.

European raspberry mite.—This mite, *Eriophyes gracilis* Nal., was rather abundant and of wide distribution in the Puyallup, Wash., district on raspberry, thimbleberry, and salmonberry. It overwinters in the buds and apparently is not fully dormant, but injures the buds during the winter. Studies of the life cycle and control of this pest are being made.

PEA APHID

The work on the pea aphid consisted in a study of the factors responsible for outbreaks and the relation between infestations and crop losses, such information to be used as a basis for control measures.

It appears that variations in moisture content of the plant, in sap concentration, and in the soil moisture have little relation to aphid abundance, but that the rate of aphid reproduction and the fluctuations in infestations during the season are closely related to the temperature. A careful study of the natural enemies of the aphid has made it more evident than formerly that they are also secondary in importance to weather in determining the intensity of aphid infestations. Studies on egg development show that only about 22 to 35 per cent of the overwintering eggs hatch and that, if eggs are exposed, without covering, to fluctuations of winter temperature, or if they are covered too heavily, the number which hatch is considerably smaller.

CELERY LEAF TIER

An intensive effort was made in 1930 to determine the summer habits of the celery leaf tier, but without obtaining conclusive results. There is evidence that in the cultivated areas breeding of the leaf tier continues to a limited extent throughout the summer, but whether or not this development is great enough to account for the large number of moths that appear in the celery seed beds in the fall at the first drop in temperature is doubtful. Last fall in the Sanford, Fla., district the season was abnormally cool and the first moth was found in the celery seed bed on September 30, when the mean temperature dropped to 77° F. The weather continued cool, with the result that there was a steady influx of moths into the celery beds throughout October. This appearance of the moths was one week later than in the previous two seasons. In the case of two earlier years, however, after the first influx about the third week in September, no moths appeared until after the next drop in temperature, which occurred during the first week of October.

The abnormally cool and wet weather which prevailed throughout the winter served to check the development of the celery leaf tier to a point at which it was unnecessary to employ control measures against it.

Control tests with pyrethrum indicated that neither hydrated lime nor sulphur should be mixed with the pyrethrum powder until shortly before it is to be used. The toxicity of such mixtures was reduced materially after they had been held for a considerable period.

The rearing of the parasite *Trichogramma minutum* Riley, using eggs of the Angoumois grain moth as hosts, has been continued, but without encouraging results. The extreme difficulty of keeping the

moth-breeding room free from mites and the red flour beetles makes the rearing of the parasites a complicated problem. Sulphur has been used as a means of reducing the mite populations, and is of some benefit in this connection, but unfortunately it reacts similarly on the parasite. Approximately 2,000,000 parasites were reared last year, most of which were used in storage experiments and in the maintenance of stocks. Rearing experiments carried on since October, 1929, to determine the effect of long-continued breeding under artificial conditions show that parasites reared in cages which permitted the entrance of all sun rays, and kept at room temperature in an indoor rearing room equipped with windows of ordinary glass, reached the fifty-fourth generation without any noticeable effects. Out of doors in similar cages the parasites have reached the forty-first generation with the same result. This parasite was active throughout the winter months, even during the abnormally cool weather of last year. Parasitism of leaf tier eggs ranged from about 3 per cent in November to 0.75 per cent in January, the percentage of parasitism being lowest between December and March.

EUROPEAN EARWIG

The European earwig continues to be a nuisance in the affected areas of Washington and Oregon and also in Rhode Island. Further studies on its food habits confirm the liking of the earwig for a diet of both animal and vegetable matter—as to the latter, it showing a preference for moss and lichens when they are available. It does, however, vary its diet according to the available food supply. Repeated reports of damage to cloth by earwigs have been received, but numerous tests with cotton and woolen cloth, both starched and unstarched and treated with fish oil, have demonstrated that the earwig will not feed upon these materials. The fish oil was added as an attractant, since in last season's work the earwig had shown a fondness for baits mixed with this oil.

Evaporation records taken with atmometer cups at 14 points in Oregon and Washington indicate that the European earwig is able to survive only in sections where the evaporation is usually below 200 cubic centimeters per week, except where some outside influence might affect atmospheric conditions. For instance, in the Hood River, Oreg., district evaporation was well over 300 cubic centimeters per week for the duration of the experiments, and at Corvallis, Oreg., it was well over 200 cubic centimeters during half of the period of observation, yet the earwig was able to survive in both of these locations. It is believed that the breeze from the ocean which follows up the Columbia River to points upstream from Hood River, and through a break in the mountains to the west, blows across a narrow strip, including Corvallis, and that this explains the survival of the earwig in this section. A transverse belt of earwig infestations is found in the Corvallis area, and this marks the southern limit of earwig abundance. At Hermiston, Oreg., the evaporation usually was well over 300 cubic centimeters, and one week it reached a peak of 432 cubic centimeters. Earwigs were able to survive here, however, because of subirrigation of the cage in which they were held. A similar condition obtained at Union, Oreg.

These instances may explain the survival of earwigs in irrigated areas about Yakima, Wash.

Fifty-four poisons, including 24 arsenicals, 17 fluorides, 5 silicofluorides, and 8 miscellaneous compounds, have been tested in bran-fish-oil baits. Potassium silicofluoride was found to be the most effective poison, with sodium silicofluoride second, and sodium fluoride third. Of the 10 most effective poisons, Paris green was the only arsenical and it ranked sixth in this group. As already indicated, fish oil is distinctly attractive to earwigs and is recommended as an ingredient of the bait.

In order to determine the effect on poultry of earwig bait containing fluorine, an experiment was conducted wherein six chickens weighing 1.3 pounds each were confined and fed entirely upon the earwig bait with the addition of meat meal to balance the ration. A chicken was removed from the coop each day. None died after being in the coop 70 hours; one death occurred after 84 hours, and another after 114 hours. The surviving chickens which had eaten the bait during their confinement for 22, 46, 70, and 114 hours, respectively, were kept under observation for two months and apparently developed normally, with one exception—that of a chick that had been in the coop for only 22 hours. It appears that there is little danger of injury to poultry from the usual application of earwig bait, as the chickens in this experiment consumed far more bait in 24 hours than would be eaten by fowls under the manner of its distribution for the control of earwigs.

VEGETABLE WEEVIL

The vegetable weevil is becoming more of a major pest of vegetables in the South each year. It is now known to occur in Mississippi, Florida, Louisiana, Texas, and Alabama. In Mississippi, Florida, and Texas four new counties became infested last year and two additional parishes were found in Louisiana.

The weevil has a wide range of food plants, including many wild species, 20 of which were first observed last year to serve as food for the weevil. A large number of these plants had been previously tested in the laboratory as possible food for the weevil. The indications, particularly since these plants have been available to the weevil since its introduction into the South, are that the food habits of the weevil are changing and that it is fast adapting itself to its new environment.

Sodium fluosilicate has given good results as a poison when incorporated in baits. Arsenicals may be used effectively on plant foliage that is not to be used for food.

In California the vegetable weevil continues to thrive in the infested areas in the vicinity of San Jose. The beetles become active about the first week in October and breed throughout the winter, but by the last of May have practically disappeared.

Barium fluosilicate has been used successfully in control of the pest, especially on carrots. This chemical does not act so quickly as sodium fluosilicate, but the latter must be used moderately or the plant is liable to injury. Sodium fluosilicate has proved to be very harmful to potato foliage, but it has been applied to tomatoes without injury.

Cleaning up grass and other débris along fence rows during the aestivation period has served to delay infestations on cultivated crops in the adjoining fields for about two weeks.

TOBACCO INSECTS

TOBACCO HORNWORMS

Although the chemotropic method of control (i. e., by attractants) of the hornworm moths is still in the experimental stage, the results obtained have been encouraging. An improved moth feeder has been devised which permits slow evaporation of the attractive substance, amyl salicylate. Tartar emetic is used as the poison with the attractant. The abormally dry season of last summer apparently reduced the numbers of the hornworm, as only late tobacco was infested to any extent. This year the moth feeders are being used at the rate of one to every 3 acres, whereas last year only one trap was used to 9 acres, and better control is resulting.

TOBACCO FLEA BEETLE

The tobacco flea beetle is still a major pest of tobacco grown under shade in Florida. Laboratory experiments and small-scale field tests conducted during the latter part of the season of 1930 indicated that from the standpoint of toxicity to the beetle and also that of safety to the tobacco plant, barium fluosilicate might be useful as a means of control.

Dusting tests with well-powdered barium fluosilicate early in the season of 1931 gave good control of the flea beetle without injury to the tobacco foliage. Under commercial conditions two applications of the barium fluosilicate were made at the rate of 4 pounds per acre with exceptionally good results. About 75 acres of shade-grown tobacco were thus treated. If subsequent results substantiate those already obtained, it is believed that definite recommendations regarding the use of barium fluosilicate for control of the flea beetle can be issued to tobacco growers.

TOBACCO STALK BORER

Further work with the tobacco stalk borer has shown this insect to be very resistant. It may live two weeks or longer completely submerged in water, as long as 70 days without feeding if water is available, and two weeks or longer without food or water. Tests conducted with different types of tobacco indicate that the variety Maryland Mammoth, an unusually vigorous type, is the most resistant to attack by the borer. *Nicotiana rustica*, one of the first tobaccos tested in the Southwest as a source of nicotine, has had to be discarded because of its susceptibility to attack. In the direct-control experiments lead arsenate appears to be repellent to the stalk borer, but does not kill so quickly as either Paris green or some of the fluorine compounds.

BLACK EUROPEAN SLUG

The black European slug made its first appearance as a pest of tobacco seed beds on the Carolina coastal plain in the early spring of 1919. Its injury was widespread and serious, and since that time

it has caused damage each season. The slugs feed at night and may destroy most of the plants in a bed before their presence is detected. The beds can be protected from them by the use of hydrated or air-slaked lime. If the slugs spend the day outside the bed and enter it at night to feed, a lime-dust barrier gives good protection. Such a barrier should be from 4 to 6 inches wide and replaced as often as necessary to keep it in the form of dust. If the slugs remain in the bed during the day, thorough dusting of the plants with the lime is effective in preventing injury.

PEPPER WEEVIL

The effect of winter temperatures and winter host-plant survival on the pepper weevil has been the subject of considerable study during the year. In general a minimum winter temperature of 28° F. or above permits such growth of the nightshade plants, the common and most abundant winter host of the pepper weevil in California, as will carry a large weevil population through the winter. Minimum winter temperatures of 30° or above permit nightshade and peppers to blossom and set fruit, thus furnishing the pepper weevil with places in which to breed and become more numerous by early summer. Minimum temperatures of 18° for short periods will kill unprotected nightshade and peppers.

The object of the later control studies has been to find substitutes for calcium arsenate. Some fluorine compounds have been tested extensively. Synthetic cryolite gave an average kill of 92 per cent of the weevils in 48 hours. When the cryolite was diluted with equal parts of talc, the average kill in a like period was 86 per cent. In 18 experiments with barium fluosilicate 65 per cent of the weevils were killed in 48 hours, while in 4 experiments calcium arsenate gave an average kill of 52 per cent during the same time. A few growers tested barium fluosilicate and, while no provision was made for making comparisons with untreated plats, weevil infestations did not increase materially where several applications had been made. No plant injury resulted from these treatments. It will be necessary to continue the experiments before drawing any definite conclusions on the exact value of either barium fluosilicate or cryolite as a control for the pepper weevil.

MOLE CRICKETS

The Porto Rico mole cricket (*Scapteriscus vicinus* Scudd.) and another species, *S. acletus* Rehn and Hebard, are becoming important pests on the eastern coastal plain and in the Gulf region, by damaging vegetable seedlings in the field and in seed beds. During the past season the latter species was particularly injurious in the winter-grown celery area of Sanford, Fla. In many instances large areas of the celery seed beds were destroyed by the insects burrowing through just below the surface of the soil. The pest was so abundant in some beds that it was necessary to apply a poisoned bait almost every day in order to protect the sprouting seed. In order to check the ravages of this insect in the celery-growing area, a more effective bait is needed, as well as baiting throughout the invaded area to prevent continued reinfestation.

The crickets may be present at any season of the year, but from February through June, when mating and egg deposition take place, they are found in greatest numbers. There is only one generation or brood annually. Fertilizers appear to be an important factor in restricting the crickets to certain areas, but this phase needs further investigation. Soil moisture and soil temperature are also important factors.

BEET LEAF HOPPER

The search for ways and means of controlling the beet leaf hopper has been continued in cooperation with the States of Idaho, Utah, and California. There had seemed to be good reasons for expecting only a light infestation in 1930 in Twin Falls, Jerome, Minidoka, and Cassia Counties, Idaho, but a heavy movement of the leaf hoppers from the Northwest, a hitherto unsuspected source of these insects, upset all calculations on the amount of leaf-hopper damage to be expected. As a result, low tonnages of sugar beets were general throughout the affected area. When the leaf hoppers arrived in the fields and it was apparent that injury would be severe, many beet plantings were plowed up under the direction of bureau workers and other crops were substituted, thus avoiding a total loss of return from the land. The southern breeding area, from which for several years had been collected data on which to base predictions of leaf-hopper abundance, contained only low insect populations until late in the summer. The experience early in the season of 1931 adds to the evidence that predictions based on data collected on leaf-hopper conditions during the winter and early spring are uncertain. As illustrated by this year's experience, the data on the hibernation of the leaf hopper collected during the winter and early spring indicated rather clearly that there would be heavy migrations to the cultivated areas; yet, because of the severe spring drought, which killed the mustards, breeding of the leaf hopper in the desert area was checked, and consequently its flight up to the third week in June was not so great as had been indicated by the overwintering populations. The leaf hoppers which entered the cultivated areas in May and June caused considerable disease in the beet fields, but the development of the disease was retarded by the cool June weather, and the beets have made a good growth. It is too early at this time to give the final effects of this year's leaf-hopper attack on the beet yield, but a large proportion of the beet fields have dangerously high populations of leaf hoppers.

The weather-vane trap devised last year was employed extensively during the present year. Approximately 100 of these traps have been placed over the territory to intercept any insects in flight from various areas on which mustards grow. That the hoppers are again coming from the South and Southwest, contrary to last season's movement, is shown definitely by these traps as well as by the distribution of the insects in the beet fields. The data from the traps also show that the insects' dispersal from the desert areas to the cultivated fields, instead of taking place in movements of short duration, extends over a considerable period.

Direct-control studies both in the laboratory and in the field have been both intensive and extensive. Various substances have been tested as attractants and repellents, but without positive results.

Either the leaf hopper is not responsive to chemotropic stimuli or else experimenal methods are yet too imperfect to reveal any reaction to chemicals on its part. The phototropic studies indicate, however, that the leaf hopper is very sensitive to light and responds to very slight differences in its intensity, the responses increasing with the intensity of the illumination within the limits covered by the tests.

An oil-pyrethrum spray has been tested to determine its efficiency as a means of controlling the leaf hopper in the beet fields. In these tests, with large leaf-hopper populations—that is, from 25 to 35 adult insects per plant—a kill of 80 per cent was obtainable. Even with this large percentage of mortality at least five to seven leaf hoppers per plant survived, so the infestation is still very dangerous from the standpoint of disease dissemination. A second application of spray reduced the number of leaf hoppers per plant to four or five. It is evident that little economic control was achieved under these conditions. Additional tests were made with calcium cyanide and other dust insecticides, and although the data thus far accumulated are not sufficient to permit definite conclusions, the indications are that the control of the leaf hopper in the beet fields by the insecticides tested is not practicable.

Another phase of control work which has received considerable attention during the year is the use of insecticides in the desert breeding grounds of the leaf hopper prior to its early summer migration. Evaluation of this method of control depends upon a thorough knowledge of the location, type, and limits of the breeding grounds involved and also the percentage of kill obtainable. Through cooperation with the University of Idaho the workers on this problem have been able to obtain information on the insect's activity in western Idaho which is essential to the work at Twin Falls. The movements of the leaf hopper in Utah throughout the year have been followed through the cooperation of the Utah Agricultural College.

The data on parasites obtained this year give a better knowledge of the limiting factors on the effectiveness of the egg parasite *Aphelinoides plutella* Gir., and also on the influence of the presence of Russian thistle (*Salsola pestifer* A. Nelson) on the percentage and distribution of this egg parasite. This parasite overwinters in Russian thistle more abundantly than in any other plant. The data collected on the distribution of this weed may explain the uneven distribution of the parasite through the desert area.

COTTON INSECTS

Investigations on insects attacking the cotton plant were carried on under the direction of B. R. Coad until January, 1931. Following the severance of Mr. Coad's connection with the department F. C. Bishopp, in addition to directing the work of the Division of Insects Affecting Man and Animals, acted in charge of the Division of Cotton Insects during the rest of the year. R. W. Harned, formerly of the Mississippi State Plant Board, was selected as leader of the bureau's work on cotton insects and reported for duty June 20. Although there was a curtailment in certain activities, the work of the division as a whole followed along much the same lines as in the preceding year.

BOLL WEEVIL

Observations on hibernation, winter survival, and resulting damage by the boll weevil were continued at several points in the Cotton Belt, some of this work being in cooperation with various State experiment stations. The average survival of boll weevils in nature, as determined from the examination of Spanish moss, made during the spring of 1930, was 0.02 live weevils per ton of moss. The survival in hibernation cages was 0.01 per cent of the number of weevils installed. This was low as compared with the average survival at Tallulah, La., which was approximately 1 per cent as determined over a long period of years. Boll-weevil infestation and damage throughout the Cotton Belt was much less than normal, yet great in the aggregate. The reduction in weevil damage seemed to be due to the low survival of weevils during the winter of 1929–30 and the extremely dry weather which prevailed over much of the Cotton Belt in the summer of 1930.

The relatively small damage caused by the pest in the vicinity of Tallulah is indicated by the fact that the average gain in seed cotton secured by the application of calcium arsenate to field plats was 105 pounds per acre, an increase of only 9.3 per cent, which is far below the average obtained in experiments during the past several years.

Cooperative work in South Carolina and Georgia has again demonstrated its usefulness to cotton farmers in these States. The hibernation, infestation, and spread of the boll weevil have been determined systematically, and through the extension agencies of the States concerned the cotton growers have been acquainted with conditions. These detailed observations have not only assembled much basic information but have made possible recommendations which would put control operations on an intelligent and substantial basis. When field observations indicated that the weevil was not sufficiently abundant to cause damage, the growers were so advised and were thus able to effect distinct savings by withholding applications of calcium arsenate.

A series of control experiments were carried out at Florence, S. C., in which the early application of poisoned molasses was followed by calcium arsenate dust where the infestation of the boll weevil had attained 10 per cent. Although boll weevils were less numerous than usual, some interesting results were obtaind from tests conducted in experimental plats. In these experiments three early applications of poisoned molasses alone showed an increase in yield over similar untreated areas at the rate of 24 pounds of seed cotton per acre. In experimental plats where calcium arsenate was the only insecticide used, five applications of calcium arsenate dust increased the yield over that of similar untreated areas at the rate of 356 pounds of seed cotton per acre. In experimental plats which were given the combination of the two treatments—i. e., three early applications of poisoned molasses followed by five applications of calcium arsenate dust—the yield from the experimental plats was increased at the rate of 640 pounds of seed cotton per acre.

During the year some reports came from South Carolina indicating that such crops as cotton, soybeans, and oats were injured by the presence in the soil of arsenic from previous applications of calcium arsenate to cotton for the control of the boll weevil. Co-

operative investigations have been arranged between the Bureau of Entomology and the South Carolina Agricultural Experiment Station to determine the facts in this matter. Preliminary inquiry indicates that the injury is apparent only on light sandy soils and where applications of excessive quantities of calcium arsenate have been made. A large number of soil samples from fields in which crops were damaged and from other fields where no poison had been applied were analyzed. Samples from fields in northeastern Louisiana which had received heavy applications of calcium arsenate and from others which had not been poisoned were also analyzed. These analyses showed that samples of soil from South Carolina taken from fields in which damage was reported had an arsenic content varying from 5 to 100 parts per million, while one sample of virgin soil showed an arsenic content of 10 parts per million. In northeastern Louisiana samples of soil from fields which had received heavy dosages of calcium arsenate with no apparent injury to the crops were found to vary in arsenic content from 40 to 120 parts per million. The several factors which appear to be responsible for this damage are not well known. It is certain, however, that the recommendations of the bureau with reference to the frequency of applications and quantity of calcium arsenate to be applied should be very closely followed.

Studies of boll-weevil migration at Tallulah, La., and Florence, S. C., have been of value in connection with determining the date on which late-summer applications of poison will cease to increase the yield of cotton.

Investigations of dusting machinery for the purpose of improving machines of various types, especially in their adaptability to distributing various kinds of insecticides, were carried on throughout the year. A number of dusting machines were calibrated and otherwise tested to secure basic information on the principles of their design and operation. These tests have led to the conclusion that the design of the dust hopper is very important in securing uniform distribution with varying amounts of poison in the hopper. Good progress has been made on designs for a hopper to meet these requirements. Attention has also been given to more efficient utilization of the higher-velocity principle in both the small dusters and the large motor-driven dusting machines. An effort has been made to develop a duster to be attached to cultivators, and some models of this type are now under practical test. Further studies of the width of the poison strips effectually covered by various types of dusters have been made. This has an important bearing on effective coverage of the plants without wasting poison. These tests have been conducted with calcium arsenate, nicotine sulphate dust, and Paris green, materials which are now widely used in the control of cotton insects.

THURBERIA WEEVIL

Life-history and seasonal-history studies of the Thurberia weevil, with special reference to its adaptation to plantings of cultivated cotton in Arizona, were continued. The weevils used for these investigations had been bred in cultivated cotton since the crop of 1926—that is, they had been removed from the native host plant four years. Into an isolated 1-acre field near Tucson 230 weevils

reared on cultivated cotton were introduced during the period from July 8 to 31. In this plot the maximum square infestation of 11.4 per cent was reached on July 22 and the maximum boll infestation of 25.2 per cent was reached on August 28. No appreciable difference was noted in the life history and behavior of the weevils bred for four years on cultivated cotton as compared with those bred on Thurberia plants in cages. Early in the season a slight preference for squares was noted, but later there was a decided preference for bolls. Preference for bolls for feeding and breeding was more pronounced in the open field than under cage conditions. Only two generations of the weevil developed during the season. Hibernation studies were continued under different conditions, and it was found that about 64 per cent of 387 weevils found in about 10,000 bolls were alive when these examinations were made on March 4 to 6.

The freedom with which the weevils transfer their attack from the native Thurberia plants to cotton was demonstrated in a field of Egyptian cotton grown on the Papago Indian Reservation, where no cultivated cotton had been grown previously. Infestation counts were made at regular intervals throughout the season. By October, 34 per cent of all bolls in the field were found to be infested. Field inspections were made at the end of the growing season to determine the development and spread of the insect. All cotton areas in the Santa Cruz Valley were found to be infested, but there was a decided decrease in weevil population as compared with that of the past few years. This condition was apparently due to the comparatively light rainfall in the mountains and the general poisoning of cotton for the control of the cotton leaf worm.

COTTON FLEA HOPPER

The so-called cotton flea hopper and certain related insects continue to be an important problem in many parts of the South. A considerable number of insecticides were tested during the year. One of the most noteworthy discoveries was the fact that a mixture of Paris green and calcium arsenate dusted on infested cotton kills large numbers of the adult hoppers. Sodium fluosilicate was found to be effective against the adults but less so against the nymphs. Four per cent nicotine sulphate in calcium arsenate dust was highly effective against both nymphs and adults. Various grades of sulphur were found to be much more effective against the nymphs than against the adults. The very fine dusting sulphurs were much more destructive to the insects than was flowers of sulphur.

Cage tests with various species of hemipterous insects have shown definitely that about a dozen species may cause the so-called hopper damage. Observations in the field, however, indicate that the injury is caused principally by three species—*Psallus seriatus* Reut., *Lygus pratensis* L., and *Adelphocoris rapidus* Say.

Investigations to determine why cotton squares are blasted by the attack of these insects have been continued. These fail to indicate the presence of any disease organism transmitted by the insects, but suggest that the injury is caused by some form of toxin, probably of a salivary nature, injected by the bugs in biting.

The time and manner of the movement of these insects from native host plants to cotton and from one field or portion of a field of cotton to another was studied by means of screens, coated with adhesives, set in and around cotton fields; by sweeping areas with nets; and by collections made by airplane. The collection by airplane of considerable numbers of the cotton flea hopper at various altitudes up to 1,000 feet is noteworthy, as is also the recovery of the wingless nymphs at altitudes of 200 and 500 feet.

PINK BOLLWORM

Research on the pink bollworm conducted in Texas was continued in cooperation with the Texas Agricultural Experiment Station. Investigations were also carried on in the Laguna district of Mexico.

Studies to determine the possibility of controlling the pink bollworm by cultural practices have been continued in the Big Bend area at Presidio, Tex., with the additional cooperation of the Division of Agricultural Engineering of the Bureau of Public Roads. Results of the experiments carried on during the year emphasize and confirm the observations reported last year.

Investigations of possible host plants of the pink bollworm, especially wild plants, were conducted in western Texas and Mexico. Experiments at Tlahualilo, Mexico, proved that *Hibiscus cardiophyllus* A. Gray, a wild plant which grows commonly in the canyon, can be infested with pink bollworm moths reared from cotton. It has also been found that the pink bollworm can survive the winter in seed capsules of this plant and reinfest it the following year.

Studies of the flight and migration habits of the pink bollworm have been continued. Observations made at Tlahualilo, Mexico, show that the flight of moths in fields of zoca or stubble cotton takes place from May to October, inclusive. The movement of moths from planted cotton occurs chiefly in August. The greater number of the females caught on the migration screens were found to contain well-developed eggs. The May flight in the zoca cotton has a distinct relationship to infestation of planted cotton. In the Big Bend area of Texas flight of the moths occurred only from the middle of September to early November and was insignificant as compared with the movement observed at Tlahualilo.

Larvæ hatching from eggs laid in cotton bolls have, in the Big Bend area at Presidio, a minimum feeding period of nine days with an average of 12.8. In other parts of the area where observations were carried on the average feeding period within the boll was 15 days. In none of the experiments did larvæ enter the overwintering or so-called long-cycle stage when the temperature averaged 77° F. or above. Below this temperature from 17 to 68 per cent of the larvæ entered the long-cycle hibernation stage. This emphasizes the importance of removing all volunteer plants from areas in which noncotton zones have been established and is an aid in determining the date of first appearance of the overwintering phases of the larvæ in the fall—a fact of importance in situations where volunteer cotton is growing in alfalfa fields from which hay may be cut and shipped.

Laboratory tests were carried out to determine the effect of moisture content of the soil on the hibernation of the pink bollworm. It was found that soils practically devoid of moisture or those containing

more than 22 per cent of moisture were decidedly unfavorable to the insects. In sandy soils the most favorable moisture content for the hibernation of the insects appeared to lie between 6 and 17 per cent, and in adobe soil the optimum moisture content was about 10 per cent.

BOLLWORM

On account of the heavy losses due to the bollworm, also known as the corn earworm, in certain sections of Texas, and a lack of specific information on the best methods of controlling this pest, special emphasis has been placed on the experimental work carried out in cooperation with the Texas Agricultural Experiment Station. The fact that the losses were found to be intensified by the presence of a number of other cotton pests made it necessary to broaden the investigations and give careful consideration to the interrelation of these insects, and the possibility of developing methods of repression which would successfully cope with several of them simultaneously. The sporadic occurrence of the bollworm also indicated the need of studying the various factors which influence bollworm infestation. Special attention was given to the significance of the proximity of cornfields to cottonfields. Under the conditions prevailing during the last growing season no close correlation was found between the degree of cotton infestation and the proximity to cornfields, although none of the cotton areas studied were more than 300 yards from corn plantings. These studies indicate that the bollworm moths are attracted to rapidly growing succulent cotton and that such cotton should be given special attention in control operations.

Striking demonstrations of the efficiency of calcium arsenate dust in bollworm control were obtained from six experimental plats. Three of these plats received 10 applications of the insecticide at 5-day intervals. They yielded at the average rate of 1,135 pounds of seed cotton per acre, while one of the untreated plats produced seed cotton at the average rate of 405 pounds per acre and the other two untreated plats produced no cotton. A series of experiments were conducted to determine the best time for beginning poison applications. These tests demonstrated the importance of beginning dusting while the larvæ of the first generation of the bollworm were still small. To illustrate: The results refererd to above may be compared with that from one plat in which the application of poison was deferred until August 9, when injury was noticeable. In this case seed cotton was produced at the rate of 909 pounds per acre. From a treated plat to which poison was not applied until August 13 and the worms of the second generation were somewhat larger, only 302 pounds of seed cotton per acre was obtained.

COTTON LEAF PERFORATOR

The cotton leaf perforator continues to cause damage in the Imperial Valley of California and in southwestern Arizona. Further investigations of the life history and habits of native host plants of this cotton pest were made in the Imperial Valley, and information on its distribution and economic importance was collected in the area to the east. In eastern Arizona, New Mexico, and Texas the insect

is present but has not become economically important. The control experiments indicate that nicotine sulphate used in a dust will kill a high percentage of the adult moths, and encouraging results were secured with combinations of nicotine sulphate and calcium arsenate. By burrowing into the bolls when the cotton plants have been defoliated by leaf worms this insect may become a pest of some importance. Injury of this type was first noted in the Salt River Valley of Arizona in the fall of 1929 and was thought to be caused by different species.

TROPICAL, SUBTROPICAL, AND ORNAMENTAL PLANT INSECTS

The work under this heading has been under the direction of A. C. Baker.

MEDITERRANEAN FRUIT FLY

Investigational work on the Mediterranean fruit fly has been carried out during the year in Florida and Hawaii.

WORK IN FLORIDA

In Florida various lines of investigation initiated in connection with the eradication effort of 1929. and concerning subjects other than those involving studies of the insect itself, were completed.

A series of reports has been submitted, dealing with the fruiting plants of Florida, both cultivated and wild, which might serve as possible hosts of the fly. The State was divided into three botanical zones and an intensive survey was made of these zones, both as to cultivated and as to wild fruits. In the course of these studies an extensive herbarium was built up. These studies included records of the blooming and fruiting periods and of the condition of fruit in relation to the fly at different times of the year. A study was made also of the individual plants in each plant association throughout the State. For example, a review of 48,746 individual plants in the high pine association shows 28 per cent host plants occurring, whereas in 42,821 plants in the low hammock association only 8 per cent of host plants occur. These studies will have special importance should the fruit fly again appear in Florida.

In the course of the fruit-fly campaign a considerable number of native fruit flies (Trypetidae) were found to infest wild and cultivated fruits in Florida. Technical studies of such flies, started during the fruit-fly campaign, have been concluded during the year. These studies cover both the biology and host relationships of the flies and descriptions of the different species. The publication of these results will greatly facilitate future identification of fruit-fly larvæ.

An important series of studies has also been made on harmful or other action of arsenic, copper, and other bait sprays on citrus and other fruit trees. The reports of this work review all the experimental and practical results obtained during the fruit-fly campaign. The harmful reaction of arsenical sprays has been confirmed, but no harmful reaction on fruit or foliage has been determined as following spraying with copper carbonate.

WORK IN HAWAII

Coincident with the practical elimiation of the fruit fly in Florida, all work involving the insect was transferred to Hawaii, together with a considerable number of the personnel formerly engaged in such work in Florida. The University of Hawaii took a keen interest in this new development and offered active cooperation, which was accepted. This resulted in the building on the university grounds of a laboratory equipped with an engine room, cold-storage rooms, constant-temperature room, sterilization room, offices, and laboratory quarters, in accordance with the designs furnished to cover the special type of investigation to be undertaken. In addition, 2 acres of ground were provided for experimental plantings. This laboratory is now under lease to the Department of Agriculture. Pending its building and equipment, the territorial board of agriculture kindly placed its new entomological laboratory at the disposal of the staff without cost.

A rather wide range of useful information on the fruit fly has been accumulated during the year.

High mortality of the fly under high temperatures has been indicated by a series of preliminary experiments. In this work different fruits were used in determining the difference in the resistance of the larvæ on different hosts. Temperatures ranging from 107° to 123° F. were used in the case of the kamani nut. It was found that a considerably longer period was required to obtain 100 per cent mortality with kamani nuts than with citrus and certain other fruits. Seven hours' exposure at 116° was required. Between 117° and 123° almost uniform 100 per cent mortality was evident in one hour. At 109° 24 hours was required and at 107°, 40 hours. This was in striking contrast to the series of experiments with loquats, in which 100 per cent mortality was obtained in seven hours at 109°. These preliminary experiments at least indicate the necessity of testing the temperature resistance with each important fruit or vegetable product.

A series of experiments was carried out to determine the effect of high temperatures on the adult flies. Flies which had been fed for different but definite periods of time after they had emerged, and flies of different origins, were used in these experiments. Under a temperature of 108° F. the range of mortality for exposures between 20 and 80 minutes was from 32 to 88 per cent. Flies of different origins and flies which had had access to different quantities of food also differed in their resistance to heat.

A series of tests was run to determine the effect of high temperatures on pupæ. The series was conducted at 110° F. and involved 11 different time periods. The results, as to percentage of mortality, gave a uniform curve beginning with the 15-minute interval up to 85 minutes, after which 100 per cent mortality appeared in all the experiments.

Experimental work with poison-bait sprays involved a series of tests run at high concentrations to determine the rapidity with which death might be obtained from increased dosage and also the possible repellent effect of the poisons. Other series were conducted in which the concentration ranged from 1 to 24 pounds of poison to 200 gallons of water. Both lead arsenate and copper carbonate were used. Quantities of less than 6 pounds of lead arsenate or 8 pounds of cop-

per carbonate hastened mortality very little. Other experiments with copper carbonate in which the quantity of sugar or sirup was varied indicated that such variation was not so important in copper mixtures as in some other poisons.

The quantity of poison required to kill flies of different ages was studied. Considerable difference in the feeding habits of flies was indicated. Some gorged themselves and others ate more sparingly, and the availability of other sources of food was necessarily an important factor. In these experiments the flies were fed a measured amount of poisoned food only once, the remainder of their food being normal. The results indicated distinct differences in the resistance of different adults and, further, that some individuals would consume the whole quantity of poisoned food while others apparently in the same condition would eat only a portion of it. Moreover, the flies would not consume a given portion of copper poison so readily as they would an equal quantity of lead arsenate. In this connection it is significant that a small quantity of copper carbonate apparently gives no mortality, whereas an equally small quantity of lead arsenate eventually results in the death of the fly. The work in Florida indicated mortality from low concentrations of copper carbonate, but in those experiments the fly had continuous access to the poisoned food as against only one feeding in the experiments here reported.

Various miscellaneous subjects were included in the work done in Hawaii, a detailed description of which is not possible in this report. Such experimentation covered the following subjects:

The influence of size of cages on oviposition. The results indicated that flies oviposited most abundantly in the smallest cages and least in the largest cages, possibly because of the closer juxtaposition of female and fruit in the former.

The relation of temperature, humidity, and period of day to occurrence and activity of adult flies. This work indicated that the most favorable temperature lies between 80° and 82° F. Relative humidity apparently exerted very little influence, but there was an increase of activity with the approach of noon, and a corresponding decrease after midday. A distinct preference was shown by the flies in Hawaii at 82° for the sunny or south side of the tree, whereas previous observations in Florida had indicated preference for the northern or shady side of the tree, probably because of the higher temperatures which occurred in Florida at the time of the observations there. This explanation is further indicated by the fact that flies in Hawaii also showed a preference for the northern or shady side of the tree when the temperature rose above 82°.

The effect of exposure of pupæ to full light. Under such exposure transformation was hastened. This is probably because of the increased temperature over the normal soil habitat rather than because of light.

The morphological characters of larvæ. Considerable differences in these features were indicated in larvæ obtained from different hosts.

The possibility of survival of the Mediterranean fruit fly on food other than fruit. These experiments indicated that flies would remain alive for more than two months on such food as they obtained on the surface of the foliage of different plants (grapefruit, mango, orange, etc.). In some of these experiments the flies had no moisture for a period of 20 days other than that which they obtained from the surface of the leaves. As a check on these experiments, flies kept in cages with the branches only of the trees (all foliage removed) died by the end of the second day, the usual starvation period. Earlier work in Mexico indicates that the food element in such survival is various wild yeasts, although a careful examination of the foliage in the Hawaiian experiments failed to indicate the presence of such yeasts in any quantity.

The percentage of infestation in different fruits and at different periods throughout the season. Striking differences were found in the degree of

infestation in oranges. For example, the Valencia gave only 0.8 pupa per sample as contrasted with 107.6 pupæ for the sour orange, and 3 for the Washington Navel orange.

The relation of ants to larval mortality. The results indicated rather high mortality where ants had access to the cages containing the larvæ which had entered the soil for pupation.

A shipment of three important Mediterranean fruit fly parasites to Spain in response to the request coming through the Spanish Embassy in Washington. This shipment reached Spain successfully and the breeding of a new stock there is now reported to be well started.

The record of parasite rearings which has been maintained by this bureau in cooperation with plant-quarantine work for a series of years. There was started this year an additional series to determine the actual percentage of infestation of fruits. This has involved some 33 fruits, and the results will indicate also the relative infestation of these fruits under Hawaiian conditions. Studies are being made, also, of the relative infestation of different varieties of the same fruit—as, for example, mangoes—where a very considerable difference of this sort is known to occur.

Relative infestation of bright and russet fruit. During the fruit-fly campaign in Florida it was observed that bright fruit was much more heavily infested than russet fruit. This preference has been confirmed by experimentation conducted in Hawaii during the year. An investigation of the rate of development of the fly in different species of fruit indicated that avocados give the most rapid, and apples the most retarded, development.

The hot-vapor system of fruit disinfection. This system, developed in Florida, has been applied in an experimental way to pineapples in Hawaii, with results indicating that it can be used with this fruit.

MEXICAN FRUIT FLY

Work at the laboratory established in Mexico City for study of the so-called Mexican fruit fly and of other related species has produced much new and useful information contained in a number of preliminary reports. These have covered (1) a cytological study of some of the more important fruit flies occurring in Mexico; (2) a study of *Opius crawfordi* Viereck, the most abundant parasite of the Mexican fruit fly; (3) investigation of the effects of temperature on the adults, pupæ, and larvæ of the Mexican fruit fly; and (4) toxicity studies in search of a satisfactory bait spray, the studies concerning chiefly arsenical and copper compounds, and indicating a marked difference of reaction between the Mediterranean species and the Mexican fruit fly.

MISCELLANEOUS

The work on fruit flies and other subtropical pests in the Canal Zone, now long standing, has concerned several species of fruit flies, some of which have not hitherto been recorded, or, if so, have been confused with other species. Several of these species occur abundantly in certain native fruits and are therefore of potential importance to cultivated fruits. Biological studies of several of these flies have been made.

The important cooperative project with the Cuban Department of Agriculture looking to the control of the black fly by importing its natural enemies from Asia was mentioned in the report of the bureau for 1930. This work, which covered two years, has been brought to a very successful conclusion during the current year. Several different types of parasites and predacious enemies of the black fly have been introduced and one of the parasites, *Eretmocerus serius* Silv.,

has multiplied to such an extent that it has been possible to make liberations throughout Cuba and also to establish colonies in the Canal Zone and in Hawaii. At present this parasite is quite generally distributed in all Provinces in Cuba, and all groves in which colonies were established prior to October, 1930, are now rated as commercially free from the fly. In addition to this parasite, a number of coccinellid beetles were introduced and one of these has demonstrated ability to do effective work.

The laboratory established at Whittier, Calif., in cooperation with citrus growers, is now fully equipped and important work has been in progress there during the past season. A considerable series of studies dealing with the resistance of the red scale to hydrocyanic acid gas fumigation—the primary purpose of the establishment of the laboratory—has been instituted. The Bureau of Chemistry and Soils is cooperating in this project through a chemist detailed to the laboratory to participate in all the chemical phases of the work. Important biological studies of the citrophilus mealybug and the red scale, including determination of the optimum temperature conditions, were also conducted at the laboratory. The results of these studies, while promising, are not ready to be made the subject of a definite report at this time. Other work in California has been the continuation of the study of thrips injury to citrus in the San Joaquin Valley and also in other parts of the State and adjoining States. This study has increased and confirmed the efficiency of control by the proper application of sulphur dust.

Studies of the insect enemies of the date palm in California, Arizona, and Texas, now centered at the laboratory at Whittier, have covered technical studies of the insect, resulting in a monographic report on its structure and anatomy, and also a continuation of experimental work on the control by high temperatures of the palm scales in date offshoots.

At the New Orleans laboratory special study on the camphor scale and the palm scale has been continued, the chemical phases of control measures being carried out through the cooperation of chemists assigned from the Bureau of Chemistry and Soils. Technical studies on the biology of both scale insects have been completed for several years. The palm scale has been steadily increasing in New Orleans, where it is a pest not only of palms but also of citrus and other plants. It recently has been reported as a pest of avocados in California. The study of natural control by parasites has indicated the inadequacy of such control, but on the other hand artificial control is easily possible, 100 per cent mortality having been obtained with an oil emulsion, using from 1 to 1.3 per cent of oil. In connection with studies of oil emulsions, carried out in cooperation with the representative of the Bureau of Chemistry and Soils, the factors influencing natural mortality have been determined so that an accurate estimate of the direct effect of the oil sprays can be made.

BULB AND GREENHOUSE INSECTS

Continued effort has been made to obtain improved or more efficient methods of destroying, by disinfection, any infestation in bulbs by bulb flies. Its purposes have been to prevent losses in the

field from the use of infested planting stock and to meet conditions imposed by the bulb-quarantine regulations on interstate transportation of bulbs. This work has been carried out in cooperation with a representative detailed from the Bureau of Chemistry and Soils and has involved fumigation with both calcium cyanide and sodium cyanide. Sodium cyanide has proved to be equally as effective as calcium cyanide and has now been authorized by the Plant Quarantine and Control Administration as an alternative for the fumigation of infested bulbs. Tests this year have substantiated earlier results, which indicated that difficulties in the fumigation of bulbs are almost entirely due to conditions of moisture in the bulbs themselves, frequently associated with certain bulb-rot organisms, making it impossible for the poison to penetrate to the larvæ. If, on the other hand, such bulbs are broken or cracked, allowing access of the gas, 100 per cent killing of bulb-fly larvæ results. No injurious effects on the bulbs were observed either in forcing or in bulb growth except where very high concentration and long exposures were employed.

The possibility of using vapor heat for killing bulb-fly maggots in bulbs was taken up last year. The idea originated as an offshoot of the disinfection of fruit for the Mediterranean fruit fly. During the current year some 19 experimental runs were conducted at Sumner, Wash., involving a total of 168 tons of planting stock and representing many of the leading commercial varieties of bulbs. While the complete data on the effect on the bulbs so treated will not be available until after the crops are harvested, cured, and weighed, the indications are very promising. The earliest lots so harvested show a substantial increase in weight over the untreated checks. The treatment consisted of holding the bulbs for four hours at a temperature of 110° F. While some injury was noted on certain lots treated at temperatures higher than 110°, no complete loss resulted. The effect in reducing field infestation of flies and nematodes was satisfactory. Similar tests were conducted at Babylon, N. Y., but here the results were less satisfactory. In this instance, again, complete records of the harvested crop are not available.

One of the new activities undertaken this year is the study of the cyclamen mite, which has been causing very heavy losses to growers of that plant. It develops, from studies made, that two different types of mites are concerned, which may occur either together or separately. These mites have also been found to attack other hosts than cyclamen. Preliminary experiments indicate the possibilities of control for these enemies by the use of hot water at a temperature between 110° and 112° F. for 15 minutes. The use of water at a temperature of 115° for 5 minutes also gave complete clean-up without injury to the plants used, 5 minutes at the lower temperatures having proved unsatisfactory. Other and perhaps simpler methods of control are being studied.

In connection with the field control of bulb flies, deep planting has been frequently recommended as a means of preventing infestation. To give experimental basis for this belief, experiments were laid down in the fall of 1929, in which six varieties of narcissus bulbs—Emperor, Spring Glory, Glory of Sassenheim, Victoria, King Alfred, and Tresserve—were planted at depths of 5, 7, and 9 inches,

respectively. These tests indicated that the lesser bulb-fly infestation was noticeably lower in the bulbs planted at the 9-inch depth, the growth and flower formation being slower and quite irregular.

A thrips, *Liothrips vaneeckei* Priesn., was brought to the attention of the bureau last January by the horticultural commissioner of Oregon, and was reported from several localities as being quite injurious to lily bulbs. This appears to be an imported species and naturally is causing concern to Oregon growers interested in the commercial production of lilies. A survey has been undertaken in the lily-growing district of Oregon to determine the distribution and actual economic status of this new pest.

INSECTS AFFECTING FOREST AND SHADE TREES, INCLUDING THE GIPSY MOTH AND THE BROWN-TAIL MOTH

The work in this field is under the direction of F. C. Craighead.

COOPERATIVE OR SERVICE WORK

The cooperative work of the division of forest insects required by far the largest part of its activities. It consisted in giving technical advice on insect control (chiefly of pine bark beetles) to the various agencies administering public lands. Large tracts of timber were surveyed, the amount of bark-beetle infestation estimated, and recommendations made for control. Technical direction and aid were given also at the time the other agencies were conducting the actual control work. Some of the more important projects conducted by the Forest Service and National Park Service under the technical direction of the Bureau of Entomology are described in the following paragraphs.

The largest project in control of bark beetles undertaken thus far was attempted in the Coeur d'Alene National Forest in the spring of 1930. A total of 600 men were employed and $135,000 was spent in combating an outbreak of the mountain pine beetle (*Dendroctonus monticolae* Hopk.) in the white pine stands of that forest, and as a result a reduction of 67 per cent in losses of the following year was obtained. An allotment of $50,000 was made for treating the remaining infestation during the spring of 1931.

Control measures against an outbreak of this insect in the white pine stands of the Kootenai National Forest were also directed. Following an expenditure of some $14,000, a reduction of 80 per cent in the 1930 infestation was secured. Other work was done in combating outbreaks of the mountain pine beetle in small areas of white pine in the Clearwater National Forest and Glacier National Park. A reduction of more than 90 per cent of the infestations was secured.

The effort to control the mountain pine beetle within the lodgepole pine stands of the Targhee, Teton, Wyoming, and Caribou National Forests was continued during the 1930 season, and approximately 72,000 trees were treated at a cost of $65,000. While the results have not been entirely satisfactory, the outbreak has been held in check and reductions in the infestation ranging from 55 to 65 per cent have been secured. This work is being continued during the present season and every effort is being made to treat as nearly 100 per cent of the infestation as possible. It is only by means of a thor-

ough clean-up of these forests that it can be determined whether reinfestation is coming from heavy centers 30 to 50 miles distant. The seriousness of this infestation lies in the fact that these forests are adjacent to the Yellowstone National Park and, if this outbreak is allowed to develop, there is no doubt that the scenic lodgepole pine forests of that region are doomed. During the 1930 season small groups of new infestations were discovered within the Madison National Forest, which borders the Yellowstone Park to the north, and within the park boundary itself. The Madison infestation apparently originated from the Beaverhead National Forest, where there has been an infestation of such magnitude that control mesures are not feasible.

Work against the mountain pine beetle was supervised in the Crater Lake and Mount Rainier National Parks. In Crater Lake National Park approximately 10,000 infested lodgepole pine trees were treated by the solar-heat method, and very good results—75 per cent reductions in infestation—were secured. In Mount Rainier National Park several small outbreaks in white pine stands were subjected to the burning and peeling methods, and it is believed that this infestation can be entirely eliminated.

Control work to reduce infestations of the western pine beetle was recommended and supervised in Oregon and California. In southern Oregon the control of this beetle occupied the attention of the private timber owners, the Forest Service, and the Bureau of Indian Affairs. Approximately $50,000 was spent in this work during the year and fairly satisfactory results in reducing the losses were obtained. Continued subnormal rainfall lowers the resistance of the pine trees and renders them more susceptible to attack. Through the control work it is hoped to keep the beetle population at a minimum until moisture conditions are again normal.

Because of the high value of the forest cover on recreational areas, active interest has been manifested in the protection of coniferous trees from destructive insects. This interest is shown particularly by owners of mountain homes, resorts, municipal and county playgrounds, etc., in southern California and in the Sierra Nevada region. Control of forest pests is equally important on public camp grounds maintained by the Forest Service and on areas leased for recreational uses within the national forests. Such work has been conducted in three such areas in southern California through the cooperative efforts of private organizations, the Forest Service, the State forester, and the Bureau of Entomology. These projects cover a relatively small area, but on account of the high values which forest cover imparts to the land are considered to be a profitable activity which should be continued as a community program on an annual maintenance basis. The Forest Service has recently included in its leases for summer-home lots a clause requiring an annual inspection and removal of infested trees on such properties.

RESEARCH WORK

The research work of the Division of Forest Insects to develop more economical and effective methods of combating outbreaks of forest pests has been very much curtailed by the necessity of conducting the cooperative and service work already discussed. The

more important of the investigational studies of the year may, however, be noted.

In connection with the work against the mountain pine beetle an intensive study of insects found in association with this destructive forest pest has been made. It is to serve as a basis for protecting and favoring the beneficial parasites and predators in connection with the application of artificial control measures. With this object in view, small-scale tests of various control measures have been carried out, some of which show promise of being worthy of further consideration.

Studies of the western pine beetle in the Modoc National Forest were continued. A series of samples representing the inner-bark conditions of infested and living trees were collected and analyzed in the laboratory at Berkeley, Calif. The results confirm those obtained in previous work, and indicate that chemical changes in the reducing sugars of the inner bark render the tree attractive to the beetles and very largely control the successful development of the larvæ. A preliminary study of the acidity of the phloem of western yellow pine indicates that the pH values may be applied in determining the susceptibility of the tree to beetle attack. This study, together with that on the sugar determination of the inner bark, has been conducted with the object of defining the nutritional requirements of the western pine beetle. A determination of these conditions in the felled tree—i. e., whether favorable or unfavorable to brood development—can be applied directly to methods of slash disposal, so as to prevent the breeding-up, in such material, of bark-beetle infestations. The California State Board of Forestry cooperated in this study by carrying the salary of an assistant for four and one-half months, and laboratory facilities have been furnished by the University of California.

Further experimental work was done to test methods of control which will protect the clerid predator of the western pine beetle and at the same time will destroy a high percentage of the beetle larvæ. It was found that the method developed the preceding year, which consists of felling trees infested by the summer brood and exposing the unpeeled logs to solar heat, was effective. This method can be applied only during the summer period, however, and should be given a thorough trial on an experimental project before it can be recommended for general use.

FOREST DEFOLIATORS

Spraying to determine the effectiveness of lead arsenate as a means of combating outbreaks of the spruce bud worm on Douglas fir was conducted within the Cody Canyon, Shoshone National Forest, during the 1930 season. The insect proved difficult to destroy with a stomach poison, because adequate coverage of the new foliage is hard to secure and because of the habit which the larvæ have of feeding concealed at the base of the new needles.

A colony of *Calosoma sycophanta* was obtained from the gipsy moth laboratory, Melrose Highlands, Mass., and liberated at Northport, Wash., where an epidemic of the Douglas fir tussock moth existed. It is hoped that this beetle enemy of the tussock moth

will become established in this region, and that it will prove to be a factor in the control of this and other defoliating insects.

A very serious outbreak of the hemlock looper was discovered late in the fall of 1930 on private lands in Pacific County, western Washington. An area of approximately 5,000 acres of hemlock forest was found to be infested. The only known method of control is by dusting the trees with arsenicals liberated from an airplane. The owners of the timber adopted plans for carrying out a project under the general supervision of the bureau's entomologists.

The Sitka spruce forests along the coast of Oregon and Washington show a very unhealthy and dying condition, caused largely by insect attack. The green spruce aphid has been found to be partly responsible for this condition in the tidewater belt. A study of causes and remedies is now under way.

PINE BEETLES IN THE SOUTHEAST

Additional data secured during 1930 support previous conclusions that outbreaks of the southern pine beetle are correlated with marked deficiencies in rainfall. During 1930 there was a deficiency in precipitation for every month of the year except September and November in the mountainous sections of western North Carolina and eastern Tennessee. In the vicinity of Asheville this amounted to 15.81 inches, and for the region in general from 6.66 to 13.97 inches for the 12-month period. During this time outbreaks of the southern pine beetle were reported from many localities in this area, and it is believed that timber losses in 1930, due to this pest, reached the high point of the past 20-year period.

WHITE-PINE WEEVIL

The records which are made yearly on the permanent sample plots in the New York-New England area showed that infestation by the white-pine weevil over the region as a whole did not increase in 1930 over 1929. In most localities there was a decrease. This may be explained, partially at least, by the fact that the preceding winter was mild and the snowfall was below normal, so that hibernating conditions were not good. The actual damage, however, was more severe than in the previous year because the percentage of leaders killed back three or more years was greater than previously noted. Drought may have contributed to this condition, the possible deficiency of moisture in the upper part of the tree forcing the larvæ to work farther down the stem in order to obtain an adequate quantity of food.

BRONZE BIRCH BORER

Considerable time was devoted to completing the studies on the decadence of birch in northern New England. These studies have shown that no one factor is responsible for the death of the trees. Insects, fungi, and physical factors occurring after the opening of the stand are important. A report of results of this work is now in manuscript form.

INSECTS AFFECTING FOREST PRODUCTS

A large number of additional wood preservatives have been under test in Panama in cooperation with the Forest Products Laboratory of the Forest Service. These long-time tests of woods treated with preservatives, as well as of wood-pulp and fiber products treated with poisons, are intended to determine protection from attack by termites, and were begun at Falls Church, Va., in 1911, and reestablished in the Canal Zone, Panama, in 1924. International cooperative work in testing wood preservatives against termites was undertaken in 1929 by the Forest Products Laboratory and this bureau. The second annual report of such cooperative work, submitted by the officials of South Africa, Australia, Hawaii, and Panama, indicated in general that these preservatives have behaved in much the same manner in these several countries and with different kinds of termites. In other words, there has been little difference in these countries as to benefits or the lack of such benefits from the different preservatives used. Other governments (Mexico, India, and Malaya) have requested that these tests be enlarged to include their countries, but owing to insufficient funds this is not possible.

The termite-proof test buildings, bridges, and tower constructed in Panama of treated timber or of termite-resistant woods, through cooperation with the American Wood Preservers Association, continue to be uninjured by termites. Two new buildings constructed of treated timber were added to these tests in 1931; the dimensions of these buildings are approximately 18 by 18 by 10 feet. Progress is being made in securing the inclusion in mandatory city building codes of the suggestions of the Bureau of Entomology for prevention of termite damage. City chambers of commerce are actively cooperating with the Bureau of Entomology in efforts to prevent termite damage to buildings. Cooperation is also being continued with the National Committee on Wood Utilization in advocating the retail sale of treated timber and its greater use in the construction of buildings.

A biological experiment of interest has been the breeding of long-winged and short-winged reproductive adults of *Reticulitermes flavipes* Kol. and the crossing of these forms to determine the origin of the castes and to solve other problems of evolution. Young termites are being secured from such crosses for the first time.

The collection of the termites of the world in the United States National Museum has been greatly enlarged during the year and is now the second largest collection in the world. It contains 795 named species, including 565 types, and much unnamed material. The catalogue and index with supplementary bibliography of the termites of the world has been brought up to date. Such a collection is invaluable in naming termites from all parts of the world.

SHADE-TREE INSECTS

The drought of last year has increased damage by shade-tree and hardy-shrub insects over much of the eastern part of the United States, as indicated by the greater demand, through correspondence and other requests, for information in this field. This year, at the request of the War Department, examinations and reports on damage of this sort in a number of the national cemeteries were made.

During the past season, the dying of the Monterey and the Italian cypress trees has presented a serious problem in southern California, where these trees are planted extensively as windbreaks and also as shade and ornamental trees. An investigation by the Division of Forest Insects indicated that the damage was caused in large part by the cypress bark beetle, but with defoliating insects and a plant disease contributing. The importance of these trees seems to warrant a thorough study of these difficulties with the object of developing methods of control.

This year, as in former years, the small appropriation available for work on insect enemies of shade and ornamental trees prevented any adequate research and experimental work in the general field. When the homes and estates, public parks, and city plantings are taken into consideration, it would seem that this is a field well worthy of expansion. With present funds it amounts largely to a correspondence project, the experimental work being negligible. During the year, however, some taxonomic work has been done, resulting in the publication of two technical papers on diprionid sawflies. A considerable number of identifications of materials submitted by correspondents have been made. A number of radio talks on insect pests of ornamentals have also been given.

GIPSY MOTH AND BROWN-TAIL MOTH

FOREIGN WORK

Field investigations have been carried on by two entomologists in Hungary, Yugoslavia, and Austria from headquarters at Budapest. Biological studies of certain insect enemies of the gipsy moth, brown-tail moth, and satin moth have been conducted, and about 185,000 parasites have been sent from these countries to the gipsy moth laboratory at Melrose Highlands, Mass. Over one-half of this material consisted of puparia of a tachinid fly, *Phorocera agilis* R. D., which is parasitic on the gipsy moth, while approximately 35,000 puparia of *Tachina larvarum* L., another tachinid parasite of the gipsy moth, and 16,000 puparia of a third tachinid, *Carcelia gnava* Meig., parasitic on the satin moth, were included. About 4,000 cocoons and adults of hymenopterous parasites were forwarded. The remainder of the material consisted of puparia of several species of tachinid flies. After considerable search, a small, light infestation of *Phyllotoma nemorata* Fall. was found at Weitersfelden, Austria, and small shipments of its hymenopterous parasites were sent to the gipsy moth laboratory. *Phyllotoma nemorata* is a sawfly which mines the leaves of birch. It gained entry into Maine and has spread into New Hampshire and Massachusetts, and it is hoped that it will be possible to establish some of its European parasites in these States.

Approximately 779,000 cocoons of the oriental hag moth (*Cnidocampa flavescens* Walk.) were sent from Japan to the gipsy moth laboratory in 1930, in order to secure a tachinid parasite, *Chaetexorista javana* B. and B., for liberation in the vicinity of Boston, Mass. Arrangements for collecting and shipping these cocoons were made by an entomologist of this bureau, engaged in Japanese beetle

investigations in Japan, who also made arrangements by which two shipments of gipsy-moth material, infected with a fungus, were sent to the laboratory from that country.

PARASITES AND PREDATORS IN NEW ENGLAND

Sample collections of the eggs, larvæ, and pupæ of the gipsy moth were made as usual in the infested New England area during the year. They indicated that one of the egg parasites, *Anastatus disparis* Ruschka, was about as important as in the previous year, while the other egg parasite, *Ooencyrtus kuvanae* Howard, showed a slight decrease. Of the parasites attacking the larvæ, *Apanteles melanoscelus* Ratz. and *Compsilura concinnata* Meig. showed an increase, while *Sturmia scutellata* R. D. remained about as efficient as before. Field observations indicated that the beetle *Calosoma sycophanta* L. destroyed a greater proportion of larvæ and pupæ than in 1929.

Dissection of brown-tail moth caterpillars from sample winter webs showed that there was a slight increase in parasitism, but there was a decrease in parasitism in the summer collections of large larvæ.

During the year approximately 50,000 adults of parasites received from Europe were liberated in New England. Of these 1,300 were mated female adults of the tachinid *Phorocera agilis* R. D., and in addition 10,000 gipsy-moth caterpillars bearing eggs of this parasite were put out. The fly was again recovered in small numbers from one locality where it was colonized in 1927 and 1928. Over 26,000 adults of *Tachina larvarum* were liberated, as well as several thousand adults of the gipsy moth's other tachinid and hymenopterous parasites. Some 9,000 adults of *Carcelia gnava* and about 2,000 adults of a species of Meteorus, both parasitic on the satin moth, were put out. Dissections of satin-moth larvæ made later indicated that the Meteorus had established itself, and during the year it was found that another recently established satin-moth parasite, *Apanteles solitarius* Ratz., had spread considerably.

Over 80,000 adults of *Chaetexorista javana* which issued from cocoons of the oriental hag moth received from Japan were released in Boston, Mass., and vicinity. Indications are that this tachinid has established itself as a result of liberations made in 1929 and 1930.

One thousand five hundred adults of *Calosoma sycophanta*, a predacious beetle introduced into New England from Europe a number of years ago, were collected by means of traps recently devised at the gipsy moth laboratory and were sent to the State of Washington. It is hoped that the beetle will become established there, especially as an enemy of the satin moth and the fir tussock moth (*Hemerocampa pseudotsugata* McD.). Over 2,000 puparia of the tachinid *Compsilura concinnata*, another long-established enemy of the gipsy moth, were also sent to the State of Washington in order that the fly might be liberated in infestations of the satin moth there, and 1,400 puparia were forwarded to the Canadian Dominion parasite laboratory to be used for the same purpose in British Columbia. Approximately 300,000 adults of the egg parasite *Anastatus disparis* of the gipsy moth were colonized in Maine and about 9,000 adults of *Calosoma sycophanta* were put out at various points in New England.

BACTERIAL AND FUNGOUS DISEASES

Attempts were again made to isolate pathogenic bacteria from gipsy-moth larvæ that died in rearing trays at the laboratory. About 50 cultures were recovered and 21 of these were used in inoculation experiments. Only one proved strikingly pathogenic and an attempt is being made to hold this form on artificial media for experiments in the summer of 1931. Several cultures recovered in 1929 were kept until 1930 and tested. Only one showed even slight pathogenicity, but virulence of the cultures may have been reduced by holding them on artificial media.

Results of an attempt to determine what is responsible for the death of certain satin-moth larvæ are inconclusive, but suggest that the larvæ may be affected by a condition similar to that producing "wilt" of gipsy-moth larvæ.

The brown-tail moth fungus (*Entomophthora aulicae* Reiche) was especially abundant in New England in the summer of 1930. Field experiments were conducted in which trees infested with satin-moth larvæ were dusted with spores of *Beauveria globulifera* Speg. and *Isaria* sp., but the results, in contrast with those obtained the previous year, were disappointing. It is as yet too early to give any information regarding results obtained from the shipments of the Japanese gipsy-moth fungus-disease material received during the year.

ATTRACTANTS

The principal conclusions to be drawn from the year's attraction experiments with the gipsy moth are as follows: Toluene, xylene, benzene, and certain gasolines were the best solvents for the preservation of female genitalia which were later exposed in the field to attract males; kieselguhr, sodium carbonate, and wool gave promise as absorbents for exposing the attractant in the field; females contained very little of the attractant when freshly emerged and the maximum amount was available two to four days later. Attempts were made to increase the percentage of emergence of moths from collected pupæ, and a simple method of sealing and preventing evaporation of the solvents in storage was devised. A manuscript covering the work that has been done on attractants at the laboratory was prepared for publication.

INSECTICIDES

Six woodland areas infested with the gipsy moth were sprayed with barium fluosilicate, cryolite, and lead arsenate. Each material was used at the rate of 4 and 5 pounds to 100 gallons of water, with 4 ounces of fish oil added to each pound of poison as a sticker. Better control was noted where lead arsenate was used. Cryolite seemed quite promising, though it did not adhere to the foliage satisfactorily.

Spraying experiments to prevent injury to the small fruit of peach showed that good control can be obtained by timely spraying with 3 pounds of lead arsenate, 3 pounds of hydrated lime, and 12 ounces of fish oil to 100 gallons of water. Experiments have been

begun to ascertain whether certain lepidopterous spruce leaf miners, especially *Epinotia nanana* Treitschke, can be satisfactorily controlled with arsenical sprays.

In tests with substances that might increase the adherence of poison dusts, talc, ferric oxide, casein glue, lampblack, bentonite, and calcium carbonate gave the best results. In connection with experiments with poison dusts, attention was given to the possibility of developing a method by which a cartridge containing the dust can be shot from a modified grenade discharger in such a way that the poison will be satisfactorily applied to the foliage of trees. It is as yet too early to give an opinion regarding the practicability of this method of application.

Various insecticides were used to ascertain to what extent they were toxic to gipsy-moth caterpillars. These tests were conducted in the laboratory, the caterpillars being confined in trays and given sprigs of foliage treated with the different poisons. With the lethal dose as a standard, the toxicities of some of the materials were as follows: Lead arsenate, 100; calcium arsenate, 100; arsenic trioxide, 60; magnesium arsenate, 50; cryolite, 45; barium fluosilicate, 35; and sodium fluosilicate, 35.

To secure information on the action of arsenicals on the leaf surface, 18 field plats were treated. Leaf collections were made from these plats before and after various quantities of rain, and these leaves were tested for pH, total arsenic, water-soluble arsenic, and tissue arsenic. As the quantity of arsenical decreased on the foliage throughout the season the percentage of solubility increased, because of the increased ratio of water over arsenical. The breaking down of arsenicals in dew, fog, and rain water on the leaf surface was found to be caused by the buffered acid condition on the leaf, by the action of carbon dioxide in setting free the arsenious acid, and by the presence of salts and impurities. In sprayed plots there was an average of 0.000025 gram of arsenious oxide (tissue arsenic) per 100 square inches beneath the leaf surface, and more in the case of injured tissue. Observations indicated that injury was much greater from the lower surface of the leaf.

During the last two years an air-pressure brush, intended especially for applying creosote to gipsy-moth egg clusters, has been devised at the laboratory. Experiments have shown that this brush can be used to advantage when creosote is to be applied to egg clusters in heavy woodland infestations. When compared with the old method of using a separate can of creosote and a brush attached to a bamboo pole, there is a saving of time and, in some cases, of creosote.

STATUS OF MOTHS

Estimates on the abundance of the gipsy moth in New England, made by employees of the Plant Quarantine and Control Administration, indicate that defoliation in 1930, as compared with that in the previous year, was considerably reduced. The acreage showing from 1 to 100 per cent defoliation in 1930 was estimated at 155,542, whereas in 1929 it was placed at 551,133.

Defoliation by the brown-tail moth in 1930 was, as has been true for the past few years, confined for the most part to areas in south-

western Maine, southeastern New Hampshire, and northeastern Massachusetts. The limits of this area were somewhat beyond those of 1929, and a rough survey indicated an increase in the acreage defoliated. Apple-tree foliage furnished the bulk of the food for the caterpillars.

INSECTS AFFECTING STORED PRODUCTS

The investigations of stored-product insects have been conducted, as formerly, under the direction of E. A. Back.

DRIED-FRUIT INSECTS

The fig moth has become a pest of increasing importance in the past several years. Its heavy infestation and widespread occurrence in dried cut fruits, figs, and especially in raisins, necessitated a study of its activities in storage and in the field as a background for control measures. Life-history studies in the laboratory, begun previously, during the year were brought to a point which is considered satisfactory for the present, and the data have been summarized for use.

As a result of cooperation extended to the bureau by the administration of the California raisin pool (organized in furtherance of the grape-control plan of the Federal Farm Board), much valuable information on the fig moth as a pest of dried fruits was obtained through surveys of storage plants storing the greater part of the 1930 raisin crop of about 160,000 tons. Of special value to science and industry were data secured on the control exerted by the parasites *Microbracon hebetor* Say and *Nemeritis canescens* Grav. and the predacious ants *Formica fusca argentata* Whlr. and others, and by high surface-soil temperatures, upon migrating fig-moth larvæ.

On investigation of the drying fields and storage houses on the ranches, fig moths were observed at night in numbers above dried fruits and over trays of drying raisins in vineyards. Infestation developing in samples of raisins taken from trays served to explain the abundance of fig-moth larvæ later developing in storage. Muscat raisins were found infested in the field to the extent of 4,300 per ton and Sultanina (Thompson seedless) to the extent of 6,200 per ton.

Late in February, 1931, examination of vines in 16 vineyards showed an average of 15.4 per cent of the vines sheltering overwintering larvæ of the fig moth under the bark. The larval population in some instances was estimated at 575 per acre. Previous search in soil, under boards, in fig orchards, etc., had revealed few larvæ of the fig moth and had failed to account for the magnitude of the population on ranches and in storage. *Microbracon hebetor* has been the chief parasite enemy of fig-moth larvæ during the year. A study of the life history of this parasite was finished during the year and a manuscript presented for publication. A life-history study of the parasite *Nemeritis canescens* has been begun.

The saw-toothed grain beetle and Indian-meal moth were not abundant during the year. In increasing to large numbers both species depend upon supplies of long-stored, unprotected dried fruits. The carry-over of raisins from the 1929 crop was not large, and figs were well protected in fumigable storage. The saw-toothed grain beetle does not develop on ranches in new-crop fruit, and dur-

ing 1930 the Indian meal moth did not do so to any appreciable extent.

Tests of materials as repellents against the dried-fruit beetle and other Nitidulidae were conducted. Cresylic acid, phenol, and oil of tar gave promise in cage tests and were tried out in a fig orchard on a small scale, with no indication of protection to the crop. Attempts to reduce injury from dried-fruit beetles by the use of traps was continued during 1930. The traps used were of the type devised at the laboratory in 1928, and were baited with slowly fermenting dried peaches. An average catch of 2,451 nitidulid beetles per trap was secured in four widely separated fig plantings. A prediction of small-to-average damage by dried-fruit beetles to the 1931 fig crop seems justified by trapping records.

Experiments with the more promising fumigants have been continued during the year. Tests with sulphur dioxide were very promising in effectiveness, cheapness, safety, and easy applicability. The vapors were developed either by burning powdered sulphur in ordinary ranch sulphuring houses or from liquefied sulphur dioxide from cylinders. Tests made in cooperation with the California Dried Fruit Association showed heavy concentrations effective with exposures of one and one-half to three minutes. For the first time the mixture of ethylene oxide and carbon dioxide snow was used in successfully treating individual 25-pound packages of raisins with a dosage of one-fourth ounce of the mixture per box. This fumigant gives promise of supplanting ethyl formate for individual-pack fumigation.

Experiments conducted in cooperation with the Deglet Noor Date Growers Association at Indio, Calif., have led to the adoption of atmospheric instead of vacuum fumigation for the treatment of the 1930 crop of dates, at a saving of $3,000. This saving in cost of treatment will be a continuing one.

The unsatisfactory market for dried figs of the 1930 crop resulted in an unusually large quantity of fruit being held in storage. Most of the crop was held in fumigable storage, largely because of past recommendations of the bureau, and this prevented insect damage which otherwise would have been serious. About 168 units of fumigable space (bins, rooms, and separate houses) were available in Fresno and its vicinity for the fumigation of figs and other dried fruits. Four years ago there were about 10 units in the same area.

During the year seven publications have been issued or prepared for publication, the most important dealing with fig insects in California. Reports were read at the Annual Institute of Fig Growers and at the annual meeting of the Dried Fruit Association of California.

PEA WEEVIL

At the request of the field-pea growers of the Northwest, and of the agricultural authorities of the States of Idaho, Washington, and Oregon, Congress appropriated funds for an investigation of the pea weevil as a pest of field peas. This investigation, begun July 1, 1930, has centered during the year at Corvallis, Oreg. The problems receiving special attention have had to do with the percentage of field infestation of the maturing crop, the hibernation of the

weevils between crops, and methods for destroying weevils in the seeds left behind in the field after harvest.

A detailed study of the infestation of crops of field peas indicates that the degree of infestation is influenced greatly by the number of successive years during which the field has been planted to peas. Other factors, such as close proximity to warehouses storing untreated peas and to fields of unharvested garden peas, were found important in this connection, but were not studied carefully. Examinations of harvested crops showed infestations ranging from 1 to 10.5 per cent in fields where only one crop of peas had been produced. In fields planted to peas for two successive years the average infestation was from 22.5 to 27 per cent. In fields planted to peas for three years or more the percentage of infestation ranged from 77 to 91 per cent. These percentages of infestation were obtained only in fields where no remedial measures had been applied.

Previous to the start of these investigations it was supposed that field infestation was brought about by adult weevils living over the winter in untreated peas stored in homes, warehouses, or other storage places. It was not believed that the adults hibernated about the pea fields. An intensive study of the number and infestation of peas left behind in the field following the different methods of harvesting and threshing brought out the practical information that from 500,000 to 3,000,000 peas per acre may be shattered and left behind on the ground. From exact counts made of all seeds found on certain areas it was estimated that in some fields the seeds left behind on the ground contained from 1,500 to more than 1,000,000 weevils per acre. It was estimated that on one 40-acre field about 47,000,000 weevils were left behind in the fallen seeds and the refuse from the threshing machines.

It had been thought that weevils thus left in the fields could not survive the winter and were not important as factors in establishing infestations in the crop of the following year. While this is possibly true in more severe climates and where the flora of the region is different, it was found that in the mild climate of the Willamette Valley in Oregon, where the foregoing studies were made, the pea weevil adults hibernate in large numbers beneath the bark scales, and in the large quantities of moss (*Usnea plicata*) which develop abundantly on the oaks about many pea fields. Examinations revealed many living adult pea weevils in the moss after the seed for the new crop had been planted.

It is evident that the present practice of fumigating only the cleaned peas in storage kills but a small number of the weevils produced in the crop, whereas the large number of weevils left in the screenings on the ground are liberated to infest the next year's crop. In seeking a method whereby the weevils in the seeds left on the ground can be killed and prevented from entering hibernating quarters, the fact was developed that the warmth of the sun causes the insects in the shattered seeds to develop to maturity and leave the seeds more rapidly than is the case with weevils in seeds sacked and carried into storage. Thus in one instance in the Willamette Valley it was found by September 17, 1930, that 339 weevils had emerged while only 22 remained in the seeds. This early emergence makes it necessary to apply control measures directly against the weevils in fallen infested seeds immediately after harvest.

Experiments indicate that, where the stubble and straw left on the field are sufficiently heavy to burn, firing the fields promises to be an effective method of destroying weevils in the peas. Examinations showed that from 99 to 100 per cent of such weevils can be killed by burning the stubble and straw. Although burning stubble and straw prevents their use for fertilizing purposes and causes some change in the method of handling fields, it will make possible the continued production of the field-pea crop provided the garden peas and the entire harvested crops are properly handled. This phase of control is still under investigation.

Reports of the pea-weevil situation in the Willamette Valley and on the hibernation habits of the pea weevil have been prepared and published.

INSECTS AFFECTING CURED TOBACCO

In accordance with provision made by Congress, an investigation of insects affecting cured tobacco was started July 1, 1930. Upon the recommendation of the president of the Tobacco Association of the United States, headquarters for this investigation were first established at Danville, Va. The discovery of the moth *Ephestia elutella* Hbn. infesting stored leaf tobacco in Richmond, Va., however, necessitated the transfer, on May 26, 1931, of headquarters from Danville to Richmond.

A preliminary survey of conditions throughout the bright-tobacco belt, including points in Georgia, South Carolina, North Carolina, and Virginia, has indicated the seriousness of the insect problem, and has been met with an instant and enthusiastic response from the industry. Wherever possible, the bureau officials have cooperated with firms conducting commercial fumigations of tobacco to determine the effectiveness of control measures applied under varying conditions for the control of the tobacco or cigarette beetle. These experiments have involved the fumigation of some 16,000,000 cubic feet of storage space and some 71,000,000 pounds of tobacco. Over 15,000,000 cubic feet of space was fumigated with hydrocyanic acid gas, over 500,000 cubic feet with carbon disulphide, and very small areas were fumigated with ethylene oxide and the mixtures of ethylene oxide and carbon dioxide.

An important development of the year was the discovery, on August 8, 1930, of a heavy infestation of *Ephestia elutella* in leaf tobacco in Richmond, Va. This is the first record of the appearance of this pest attacking leaf tobacco in the United States. The infestation was general throughout about 8,000,000 cubic feet of warehouse space holding about 31,000,000 pounds of leaf tobacco, mostly of the flue-cured variety, and valued at about $10,500,000. The infestation was heaviest in the brightest and most valuable grades. Scouting operations, immediately instituted after the discovery of the pest, indicated that the Ephestia was confined to a very small area in Richmond and, fortunately, one isolated from other tobacco establishments in that city. No other instances of infestation were found in tobacco storage throughout the bright-tobacco belt, and it is hoped that the large-scale fumigations immediately authorized by the department have resulted in stamping out this pest.

Several articles giving information regarding *Ephestia elutella* as a pest of cured tobacco have been published or are in the process of publication.

A thorough study of the biology of insect pests of cured tobacco and of the methods for their control has been begun.

FLOUR-MILL INSECTS

The investigation of insects affecting flour mills has been continued during the year, with headquarters at Manhattan, Kans., and Sligo, Md. The work in the southwestern milling district has been confined mostly to determining the relative value of various common commercial fumigants, and in developing a program of control that will be less expensive and yet assure satisfactory freedom from insects. Some attention has been given to vault and warehouse fumigation in flour mills, and to the destruction of insects in the stream of wheat as it enters the mill. It is believed that the insects brought into the mill from the elevator bins along with the stream of wheat are largely responsible for reinfesting milling equipment that apparently has been successfully treated by heat or fumigants. Equipment for heating grain as it enters the mill has been used as a basis for this experiment, but convincing data have not yet been secured.

An intensive study of the biology of the insects chiefly responsible for the infestation of export flour has been continued, and a preliminary report on the life history of the flour beetles, *Tribolium confusum* Duv. and *T. ferrugineum* Fab., has been prepared. It was found that adult beetles may live two years or more and that the female beetle may lay nearly 1,000 eggs over an oviposition period of more than a year. During warm summer weather the life cycle is normally completed in about six weeks but may be prolonged to four months on the less nutritious foods and at lower temperatures.

The predacious mite *Acarophenax tribolii* Newst. and Duv. was first recorded as being observed in North America during the year. It was found in Virginia, the District of Columbia, Maryland, Mississippi, and Texas. The only previous recorded hosts are the tenebrionids *Tribolium confusum* and *T. ferrugineum*. Other hosts found infested are *Gnathocerus cornutus* Fab., *Palorus ratzeburgi* Wissm., and *Latheticus oryzae* Waterh. The young female mites live first upon the adult beetle, later migrating to an egg; they then become greatly distended and die, the young soon afterwards emerging from the parent's body as adults. Ordinarily this mite seems to be of little economic importance.

INSECTS AFFECTING STORED GRAIN

The report of last year announced the discovery by department experts of the ethylene oxide-carbon dioxide mixture as an effective fumigant for grain in terminal elevators. Experiments with this fumigant have been continued during the year with gratifying results, and many thousands of bushels of wheat have been successfully fumigated without fire or explosion hazard and with no danger to the operator or injury to the wheat. Publications have been prepared and are now available for distribution describing this method of fumigating elevators.

A new departure in the investigational work of the year has been an attempt to introduce the ethylene oxide-carbon dioxide mixture in the form of a vapor or gas into the column of wheat by means of a piping system permanently installed in the elevator bin. After the bins have been filled and closed the vapors are introduced directly from the steel cylinders containing the fumigating mixture. It is hoped that this method will prove more satisfactory than shoveling the ethylene oxide-carbon dioxide snow mixture into the stream of wheat entering the bin, as described in the last report. The results of experiments already conducted are very encouraging. Laurel Duval, of the New York Produce Exchange, the Carbide & Carbon Chemicals Corporation, and the Bureaus of Entomology, Chemistry and Soils, and Agricultural Economics are cooperating in this work.

The study of the rice weevil as a pest of corn on southern farms has continued during the year. Whereas several years ago the ears of corn grown on St. Simon Island, Glynn County, Ga., were infested at harvest time to the extent of 80 to 90 per cent, and corn in storage there was always destroyed before May following harvest, the construction of fumigable bins or cribs and the treatment of the corn in the cribs after harvest and again in the spring before May 1 has reduced field infestation at harvest time to about 1 per cent of the ears. This and other work in the southern corn belt indicate that each locality raises its own weevils, that there is very little migration of weevils from farm to farm, and that where buildings on farms are reasonably well separated the percentage of ears infested with the rice weevil at harvest time is dependent almost entirely upon the amount of untreated corn in storage on the farm after May 1.

BEAN WEEVILS

The bean-weevil investigations were established at Modesto, Calif., in January, 1928, in response to an urgent call for assistance made by the bean-growing interests of that section. At all times the bureau agents have had the most hearty cooperation of warehouse operators, bean growers, and State and county agricultural authorities and local chambers of commerce.

During the year the work has been continued along lines discussed in previous reports. The work of detecting and stamping out infestations on ranches and in storage has been continued. About 4,650 samples of beans taken from lots consigned to warehouses by farmers were examined during the period between September, 1930, and February, 1931, and about 30 per cent of the samples were found infested. Because of the large carry-over from the 1930 crop stored in warehouses, about 1,400 additional samples were examined during the March–June period of 1931.

While information gained from examination of these samples has been used to the great advantage of both producer and warehouseman, since it has indicated need for treatment to prevent unsuspected deterioration of the crop in storage, this work was undertaken primarily as part of a large and long-continuing research project of which the object is to determine whether it is possible to bring an important and widespread pest of a com-

mercial crop under satisfactory control by intelligent application, throughout an entire district, of remedial measures such as the destruction of weevils in storage. The conditions with regard to bean weevils in the Modesto district have improved each year since 1927, and it is believed that this improvement is the result of this work.

HOUSEHOLD INSECTS

Of special interest during the year has been the continued improvement of a method of storing furs and fabrics by combining tight storage with effective fumigation. Observations thus far indicate that this method of storage in specially constructed burglar-proof and fire-proof vaults is dependable. So far as can be determined from experience extending over six or seven years, it can be followed without affecting the luster or other characteristics of tanned furs and with complete effectiveness in destruction of insects.

The work with mothproofing solutions, mentioned in a previous report, has been continued during the year and a special study of the value of paradichlorobenzene as a control for household pests, particularly clothes moths, has been undertaken and is still in progress.

INSECTS AFFECTING CONFECTIONS AND NUT MEATS

The investigation of insects affecting confections and nut meats has continued during the year. Special attention has been given to experiments furnishing data on the best methods of protecting the raw products of the industry from insect attack.

INSECTS AFFECTING MAN AND ANIMALS

These investigations have continued under the direction of F. C. Bishopp.

SCREW-WORM FLY AND OTHER BLOWFLIES

Special attention has been given to increasing the effectiveness of controlling the screw worm and fleece worm by flytrapping and to determining the true value of different methods of trap operation. The large-scale range-trapping experiment has been continued and enlarged. The area selected for this experiment is in the rough range country in Menard County, Tex., where screw worms are very destructive and where the ranchmen have shown a splendid spirit of cooperation. The experimental area now covered by flytraps is somewhat more than 100,000 acres. The check, or untrapped, area used for comparison contains about 133,000 acres. Throughout these two areas are being kept records of the number of screw-worm and fleece-worm cases and the approximate number of treatments required to cure them, the kind of animals attacked, and the probable cause of the infestation. Careful checking of the number of flies present in the trapped and control areas showed that apparently the trapping operations during the past season had decreased the fly population 36.2 per cent. The value of the operation of traps is indicated by the fact that 1,945 quarts of flies were captured in 269 traps between March 2 and April 10. Investigations of various factors influencing the number of flies caught have been continued. These factors in-

clude trap location, size of bait used, frequency of adding bait and water, and kind and amount of materials added to the baits to prevent larvæ from breeding in the bait pans. Definite conclusions can be drawn only after accurate data have been accumulated over a period of several years.

Some attention has been given to modifying trap design. The large box trap developed recently has been tested under practical conditions and appears to have some distinct advantages. It not only captures large quantities of flies but also facilitates the disposal of carcasses. A portable trap sufficiently large to take medium-size carcasses was designed, and a number of practical tests made with it. In one of these tests 28 gallons of flies were captured in six weeks. Efforts to develop parasites on the fly larvæ and pupæ in these traps have been rather disappointing. Certain parasites and predacious enemies, however, appear to be of value in reducing the number of screw worms in some localities. Investigations were therefore undertaken to determine more accurately the distribution and local abundance of these beneficial insects.

The abundance of the larval parasite *Brachymeria fonscolombei* Dufour on ranches in the vicinity of Uvalde, Tex., where releases of this parasite were made last year, was somewhat less than last season, the average parasitism this year being about 30 per cent, whereas the previous year it was more than 39 per cent. The pupal parasite *Mormoniella vitripennis* Walk. showed a slight increase, however, the percentage of parasitism being 1.42 as compared with 1.25 the previous season. Parasitic wasps of the genus Aspicera appear to be of some practical value, and their distribution and life history and the methods of propagating them for dissemination are being studied.

Investigations have been continued on methods of protecting infested livestock from further attack. Designs for screening houses for this purpose have been given consideration and tests have developed the practical value of such houses under ranch conditions, especially where purebred animals are to be treated. The location of hospital pastures has been found to have a distinct bearing on the rapidity with which screw-worm cases can be cured. By the simple method of changing the hospital pasture to high ground, free from underbrush and with comparatively few trees, the recovery of screw-worm cases has been materially facilitated.

CATTLE GRUBS

Certain phases of the cattle-grub investigations have been continued in cooperation with the Bureau of Animal Industry. The efficacy and ease with which insecticides can be applied to the backs of cattle have been increased. Derris and its derivatives appear to be most promising, particularly since there is no danger of poisoning livestock with them.

Investigations of the distribution of the northern cattle grub indicate that this serious pest is still spreading. It is increasing in abundance in the areas infested and its presence in Oregon was determined for the first time.

On account of the prevalence of the idea that the use of fly sprays is an effective method of control, tests have been carried out to

determine this point. The results of the experiments this year indicate that neither light nor heavy oil sprays have significant effect on warble infestation.

Investigations of the factors responsible for the natural freedom of certain areas from cattle grubs were continued, particularly in the Red River Valley of the North. In this, the third year since the laboratory has been located at Fargo, N. Dak., an exceptionally dry spring prevailed and therefore the experiments in this region were seriously hampered again. The fact that cattle grubs appeared in certain parts of the Red River Valley in the spring of 1931 is added evidence that the combination of type of soil and climatic factors has an important bearing on the presence or absence of infestation in that area.

SHEEP SCAB MITE AND GOAT LICE

The cooperative work on these important sheep and goat parasites was continued with the Texas Experiment Station at Sonora, Tex.

The work on the sheep scab mite has been terminated and a report on the results of this investigation is being prepared for publication. A number of large-scale tests of sulphur dips against goat lice were carried out. The efficacy of the finely divided sulphurs in combination with a small amount of soap has been fully demonstrated against all species of goat lice, and as a result eradication of goat lice on a range basis, or throughout large areas, appears to be entirely practicable.

EYE GNATS

It has been established that eye gnats (*Hippelates* spp.), which so seriously hamper agriculture and other activities in certain valleys in southeastern California and in parts of the Southern States, breed in decaying organic material. These insects have been reared on various kinds of vegetable and animal refuse. This strongly indicates the importance of more adequate disposal of home and farm wastes. Much attention has been given to the development of cheap and effective traps for use against the gnats and several different types which work well have been tested. The season's work seems to show that extensive trapping not only greatly reduces the annoyance from the gnats but may serve gradually to reduce the pest in a given locality. These trapping operations, which have been carried out in cooperation with local authorities, have resulted in a decrease in the number of cases of eye diseases which have heretofore seriously hampered work and interfered with schools.

MOSQUITOES

Additional funds provided for mosquito work in the Northwest permitted the establishment of a laboratory at Portland, Oreg., for a study of the flood-water mosquitoes which have been an extremely serious pest in that region. It has been determined that the two principal mosquito pests of this region are *Aedes vexans* Meig. and *A. aldrichi* D. and K. The outbreaks are clearly associated with the appearance of pools along the rivers after floods. These mosquitoes pass the winter in the egg stage, and when the eggs are sub-

merged in the spring they hatch and the young develop in the pools in incredible numbers. Some of the eggs remain unhatched until they have been submerged several times. A survey of the principal breeding areas along the lower Columbia River has been made, and experiments with different methods of control have been carried out in cooperation with the local authorities. The timely application of distillate oil was found to destroy a large percentage of the larvæ.

The laboratory for the study of malarial mosquitoes was moved from Mound, La., to Orlando, Fla. The extensive studies of natural environmental conditions in the Anopheles-breeding and nonbreeding waters of the Louisiana delta region were thus terminated, and the material gathered there was prepared for publication. The analysis of these data shows that all waters studied were apparently suitable for Anopheles breeding from the standpoint of larval food supply, the abundance of larvæ depending upon the kind and amount of protection from natural enemies afforded by various plants and by floating débris. The range of hydrogen-ion concentration in the breeding and nonbreeding waters was found to be essentially the same, and practically all waters were alkaline in reaction. Investigations of the important pest mosquito *Mansonia perturbans* Walk. were continued in Florida. The peculiar habit of the larvæ and pupæ of this mosquito, which pierce submerged stems and roots of plants to obtain air, makes their control very difficult. In central Florida larvæ were found attached to the following plants: Pickerel weed, arrowhead, cattail, frog's bit, yellow waterlily, and water-hyacinth. Sluggish streams or marshes having weedy bottoms and in which the above plants grow in abundance are the principal breeding places of this mosquito. Life-history data indicate that there are two broods of adults in Florida, as two definite peaks of abundance were noted during the season, the first occurring early in May and the second about the first of August. Discovery that the young larvæ live at the surface of the water for a short time after the eggs hatch, and that the pupæ rise to the surface of the water several hours before the adults emerge, suggests that oiling may be effective if it is done at the proper time.

Certain foreign reports have directed much attention to the question of the relationship between the extensive cultivation of certain legumes and the incidence of malaria. Numerous requests for information on this subject prompted the conduct of some experiments to determine whether Anopheles mosquitoes would, in fact, feed on these plants and whether the nectar would adversely affect the mosquito or the malarial organism in it. The preliminary experiments along this line indicate that the mosquitoes would not feed to any extent on these legumes.

SAND FLIES

Increased funds were granted to the bureau to begin work on the problem of the sand fly in the Southeast. A laboratory was established at Charleston, S. C., and information was gathered on the species of sand flies concerned, the distribution of these insects as pests, and the environmental conditions favoring their abundance. Prior to the beginning of these investigations practically no authen-

tic information had been obtained on this important group of insects. Sand flies were found to be of some economic importance along the entire Atlantic seaboard from Massachusetts to Florida, and in all the Gulf States. They were most abundant and annoying near salt water at fresh-water inlets. However, certain species were also reported from the interior. Several species of sand flies are involved and they appear to have a more or less restricted seasonal incidence. The young of certain of these species have been found in the short-grass and in the mangrove marshes. The larvæ have been taken in considerable numbers from fiddler-crab holes and in the silt along waterways and ditches. Investigations have been undertaken to determine the biologies of the different species and to study their food requirements in detail. It has been shown that the sand-fly larvæ develop very slowly in cool weather and can pass the entire winter in the larval stage; also that the larvæ are capable of withstanding temperatures as low as 40° F. Some preliminary investigations with repellents indicate that fair protection from these insects may be obtained by the use of the oils of camphor, bay, sassafras, and pine. Pure glycerin was found to be even more effective than the essential oils. Oil of pine tar and certain hardwood oils were found to be effective for some time in keeping sand flies from passing through screens, and kerosene applied to screens gave protection throughout a night.

RAT MITE AND ENDEMIC TYPHUS

For some time investigators of this bureau have suspected from epidemiological data a connection between the tropical rat mite (*Liponyssus bacoti* Hirst) and endemic typhus. Experiments conducted in cooperation with a medical research worker have proved that this mite not only causes a dermatitis of man but that it is capable of transmitting endemic typhus. This is a discovery of outstanding importance, as the disease is widespread in this country. The methods used and results attained in this study were demonstrated at the general exhibit of the American Medical Association at Philadelphia in June, 1931, and received the silver award of the association.

REINDEER INSECTS

Investigations of two very important reindeer botflies, *Oedemagena tarandi* L. and *Cephenomyia trompi* L., were conducted in cooperation with the Alaska Agricultural Experiment Station with headquarters at Nome, Alaska. The methods of handling the reindeer on the range make the application of control practices extremely difficult. An experiment was undertaken to decide the feasibility of reducing these pests by pasture rotation. The results of this test can not be determined for several months. A number of reindeer were sprayed with different insecticides. Their dense coats make it extremely difficult to bring the insecticides into contact with the skin, and special nozzles and methods of application are being developed. Life-history and seasonal-history studies of the insects are also in progress.

POULTRY PARASITES

Experiments have been conducted to determine the efficacy of applying nicotine sulphate to the roosts for the control of lice, mites, and other ectoparasites of poultry. These experiments showed that a light application of this material shortly before the fowls go to roost would effect a high degree of control of the lice, but that at least three treatments at 8-day intervals are necessary under ideal conditions to eliminate all lice from a flock. It was concluded that where eradication was desired the use of sodium fluoride would be most economical and certain. Nicotine sulphate did not destroy sticktight fleas attached to fowls, but its use as a spray when diluted 1 to 10 gave satisfactory control of the common chicken mite.

The occurrence of the pigeon fly (*Pseudolynchia maura* Bigot) as a serious factor in commercial loss led to some studies of this pest. Treating the birds with any one of several different insecticides and at the same time systematically destroying the pupæ in the nest boxes gave practical control.

MISCELLANEOUS WORK

Preliminary investigations of the transmission of relapsing fever of man by the tick *Ornithodoros turicata* Dugès were carried out. A well-defined case of the disease developed in one of the investigators following the bites of this tick, which occurred in a cave. The transmission of this disease by *O. turicata* was demonstrated by allowing specimens of the tick collected in nature to feed on guinea pigs.

A severe outbreak of buffalo gnats occurred in portions of Mississippi and Arkansas in the spring of 1931, and a preliminary investigation showed that *Eusimulium pecuarum* Riley was the species concerned. The outbreak was unusual in that it occurred in the absence of overflows which usually have been associated with such events. Apparently the extremely low level of the streams last year induced the growth of vegetation along their beds, and the return of normal water levels created places of attachment and development.

BEE CULTURE

The Division of Bee Culture is under the direction of James I. Hambleton, with headquarters at Somerset, Md.

INSEMINATION OF QUEEN BEES

The work on hand insemination of queen bees at the southern laboratory has been continued, but has been confined almost entirely to a simplification of the method. Hand-mated queens have been compared with naturally mated queens to determine the degree of insemination. Failure to mate has caused a heavy loss of queens by breeders over considerable portions of the South this year. Observations are being made to determine the cause of this loss. A critical study of the effect of food, colony development, and age upon the sexual development of both queens and drones is under way. Several hundred queens have been collected, preserved, and sectioned in studying the correlation of the number of egg tubules in the ovaries with the prolificacy and breeding qualities of queens.

At Somerset improvements have been made in the Watson method for artificial insemination of queen bees. By the use of a special clip and an accessory rod it is possible to hold the tips of the queen's abdomen apart during the operation. This frees the left hand, which under the old method held a pair of fine forceps which kept the abdominal tips separated. By the use of the clip the abdominal tips can be spread wider apart, and the danger of injuring the delicate tissues of the queen bee is minimized. A change has also been made in the manner of confining the queens during the test period after the operation. The queens are now kept in 10-frame hive bodies screened into two or more compartments, each with its own entrance. The hive bodies are tiered in the usual manner. Virgins from the F_2 generation have been used during the year, and between 30 and 40 per cent of the queens operated upon have shown some degree of insemination. Improvements have also been made in the technic of catching and marking drones, so that it is possible to keep an accurate record of the parentage and age of the drones used in the experiments. The use of the electric incubator in rearing queen bees has been quite successful and conserves the supply of bees necessary for the work. Improvements have also been made which facilitate grafting, so that it can be done with success even on unfavorable days. A paper dealing with the artificial insemination of queen bees was prepared.

POLLINATION OF RED CLOVER

Rather significant results were obtained in the experiments on pollination of red clover by honeybees. The experiments were begun at Holgate, Ohio, last summer in cooperation with the Bureau of Plant Industry. Some colonies of honeybees were concentrated in the vicinity of red-clover fields, and in other cases cages were used to confine honeybees to definite plats of red clover. It would appear that the bees were an important factor in the set of red-clover seed under the conditions existing in Ohio during the summer of 1930, although because of the drought the conditions were probably not average. The experiments are being continued, and if this season is normal it will be possible to compare the results of the two seasons' work and arrive at some definite estimate of the value of honeybees in the pollination of this legume. A report on the results of the work in 1930 was submitted, but it is planned to wait until this year's work is completed before publishing a full report.

Rather exaggerated claims have been made that Caucasian bees are more effective in pollination because of their inclination to fly under more adverse weather conditions than do Italian bees. In order to learn whether such a difference actually exists, preliminary experiments were begun this spring.

FLIGHT OF THE BEE

The studies of the flight range of the honeybee were continued at the intermountain laboratory during the summer of 1930 in an effort to determine the distribution of bees from an apiary located within a source of nectar. Observations were made on the flight of bees from apiaries located in the San Luis Valley of Colorado and

in the vicinity of Laramie, Wyo. It was found that the bees have a tendency to concentrate their flight in only one or two major directions from an apiary, even though nectar-secreting plants of equal attractiveness are present in other directions and closer to the colonies. Bees were found to fly as far as 2¾ miles for nectar and pollen in the major direction of flight, neglecting nearer fields in other directions. It was not possible to explain this concentration of direction of flight as caused by weather or topographical differences in the terrain. Where several apiaries were located in fairly close proximity to each other, the bees from the different apiaries did not seem to trespass on each other's fields to any great extent.

Because of the need for accurate knowledge on the rate of flight of bees from colonies and packages, work has been started at Somerset, Md., to devise a photoelectric apparatus which will accurately and chronologically record the flight of bees from full working colonies. This type of apparatus has long been needed in experiments dealing with the activities of field bees.

DISEASES OF BEES

Reports have been received from various parts of the country that beekeepers and inspectors have had difficulty in distinguishing between American and European foulbrood in the apiary, because under certain conditions the scales of the two diseases closely resemble each other. A study of these confusing cases showed that with some practice the two diseases can readily be distinguished by the odor from a single scale. Familiarity with the odors typical of the two foulbroods facilitates making an accurate diagnosis in the apiary. A brief report of this work was published in an outside journal.

In connection with the use of 20 per cent formalin-water solution for disinfecting American foulbrood combs, preliminary results indicate that the temperature at which the combs are treated is a highly important factor, but has largely been neglected by practical beekeepers. Tight covering of the treated combs after they are removed from the disinfectant solution is of considerable importance in prolonging the period of disinfection.

In certain sections of the Western States heavy losses of adult bees have occurred from a condition commonly known as paralysis, the exact cause of which has never been determined. From cage experiments with sick bees obtained from Nevada it appears that the condition can be transmitted to healthy bees, thus demonstrating its infectious nature, although it has not been possible to inoculate strong colonies under experimental conditions.

During the year 905 samples of brood and adult bees were submitted for diagnosis. This number included numerous samples of comb treated for American foulbrood, which had been sent to the laboratory for sterility tests. Ninety-six imported queen bees were received and examined for *Acarapis woodi* Rennie, a mite parasitic on the honeybee, which occurs in various European countries. Mites were not detected in any of the shipments. The disease caused by the mite, commonly called Isle of Wight or acarine disease, has never been reported as occurring in the United States.

Studies of the spread of American foulbrood in commercial apiaries in relation to the minimum number of spores of *Bacillus larvae* necessary to produce the disease are still in progress at the intermountain laboratory, Laramie, Wyo. A series of colonies of different strains of bees were fed the previously determined minimum infective number of spores, 50,000,000 per liter, without developing disease in any case. Individual larvæ were also fed a definite number of spores to determine the minimum infective dose of spores per larva. While difficulties were encountered in these preliminary experiments, one series of individual larvæ fed 10,000,000 spores per larva developed disease. Although the results are as yet insufficient to be conclusive, they again seem to indicate that the minimum infective dose of spores of *Bacillus larvae* necessary to produce disease either in a colony or in an individual larva must be relatively large. Studies on the minimum number of spores of *Bacillus larvae* per cubic centimeter of seeding that would produce growth on artificial culture media have been continued. The smaller number of spores tended to require longer periods of incubation in order to produce growth, and fewer than 50,000 spores per cubic centimeter produced no growth even after 30 days' incubation. There was, however, a variation in results caused by the variable character in the spores known as dormancy, which prevented more than a slight negative correlation. By means of centrifugation and microscopic examination it has been possible to demonstrate the presence or absence of spores of *Bacillus larvae* in commercial honeys, and although the method employed is not satisfactory or reliable in the case of negative results, it was possible to demonstrate the presence of spores in 13 out of 133 samples of commercial honeys bought on the open market at widely scattered points in the United States. Whether the 13 samples contained sufficient numbers of spores to inoculate healthy colonies was not determined. These studies are being continued. The results of the work thus far have been incorporated in a paper submitted for publication.

INTERMOUNTAIN LABORATORY

The work in the Intermountain States dealing with the cost of honey production and with apiary management, which has been conducted in cooperation with the Bureau of Agricultural Economics and State beekeeping specialists, has been terminated. All the records from the cooperators are now being assembled preparatory to issuing a final report of the work in this region. Similar work with cooperators is being continued in the so-called "white-clover" States of the Great Lakes region. If the records from the cooperators at the conclusion of the season are found adequate, it is planned to discontinue the work in this region.

Studies of various methods of wintering in the intermountain region were continued. Colonies going into winter quarters with two or three times as many young bees as the average colony has, were found to consume more stores, but considerable differences in their condition were found in the spring, some coming through the winter no better than average colonies while others had more than the average quantity of bees and brood. One colony, which was placed in winter quarters presumably with old bees only, wintered

successfully and a sufficient number survived to raise a new generation in the spring, which later built up to average size during the dandelion flow. No significant variation between the stores consumed during the winter and the number of frames of brood in the spring was found in colonies that were wintered by four common methods.

SOUTHERN LABORATORY

Investigations of importance to the beekeeping industry in the Southern States have been continued at Baton Rouge, La., in cooperation with the Louisiana State University. In response to requests from the producers and shippers of package bees and queens, a study of the various types and sizes of shipping cages was made for the purpose of reducing, if possible, the number of those types and sizes and of minimizing the loss of bees in transit. The shipper, the receiver, and the public carrier have been dissatisfied with existing conditions in the package-bee business, but it has been extremely difficult to obtain the cooperation among the various factions which is necessary in order to solve their problems satisfactorily. Each producer designed and used a cage which seemed to him ideal. Many had undoubted merit, but none was entirely satisfactory and only a few shippers seemed willing to make compromises in the interest of simplicity and standardization. The public carriers charged a high rate for transportation because of the risk of losses in transit, and because of the wide differences in type and size of cages received for shipment. The receiver of package bees never knew what kind of a package to expect when he ordered bees from a southern shipper, and as a result there was much dissatisfaction. After interviewing many shippers and studying many types and sizes of cages, it was finally possible to recommend a minimum number of styles of cages, and these have been described in a multigraphed circular entitled "Recommendations for Shipping Cages for Bees." It is hoped that the recommendations embodied in this circular will serve as a basis for improving the package-shipping business, and that the adoption of uniform cages and methods of shipping may bring about a reduction of transportation costs. Investigations are also in progress to learn the most suitable size of package per unit of adult bees, and the effects of foods of various kinds and of high and low temperatures during transit.

Considerable attention is being given to the management of colonies for straight honey production under southern conditions, and to the supersedure of queens, particularly those sent through the mails or by express in packages.

The work on honey and pollen plants in the South has been continued, and interesting facts about the importance and value of certain honey plants have been learned by placing colonies of bees on scales in the care of collaborators living in areas where a single species of plant predominates. Emphasis is being placed on the influence of soil and environment on nectar secretion, with the probability that the study will be concentrated on a single species of plant grown under closely controlled conditions. An herbarium has been established which already contains over 100 mounted, identified, and labeled nectar and pollen plants. In conjunction with the study

of honey plants, scale records of the weight changes of a colony of bees are being compiled.

PACIFIC COAST LABORATORY

As a result of funds being made available for establishing an apicultural research laboratory on the Pacific coast, Davis, Calif., was chosen as the site of the laboratory, and actual work was started in March, 1931, under a cooperative agreement with the University of California. Because of the lateness of the season, it was not possible to begin work on the two major problems selected for study—namely, an economic survey of beekeeping on the Pacific coast and a survey of existing conditions relative to bees and pollination.

An economic survey of beekeeping in Oregon is to be commenced in January, 1932, in cooperation with the Oregon Agricultural College. This survey will cover beekeeping enterprises in the major honey-producing districts of the State. A similar survey is planned for California although the time when the work can be started has not been determined. A thorough survey of beekeeping conditions in California is greatly needed. Changes in agricultural practices have caused considerable upsets in what were at one time proved and successful methods of producing honey. In the San Joaquin and Sacramento Valleys growing alfalfa for seed has almost ceased, and bees now have opportunity to store alfalfa honey only in the Imperial Valley. Large areas have been put into fruit and vegetables, which produce early nectar; and into beans and cotton, which produce nectar later in the season, leaving a long period of dearth when the bees have no source of supply and must consume the stores already gathered. In a poor season many colonies starve. Either the bees in these areas must be moved to new locations or new systems of management must be inaugurated, if honey production is to be maintained on a profitable basis.

At the end of the early fruit bloom, colonies of bees in the San Joaquin and Sacramento Valleys in California become exceedingly populous at a time when there is no nectar to be gathered. As a result, producers of this region have found it advantageous to ship package bees into Canada or elsewhere either for pollination purposes or for honey production. It is possible that these surplus bees can also be used in the orange region, where colonies are usually too weak to store a full crop of orange honey.

Preliminary studies of the possibilities of utilizing the nectar-producing flora of the foothills and in the Sierras adjoining the San Joaquin and Sacramento Valleys have been made. Because of the prevalence of California buckeye, it is unwise to move bees into new territories until some way is found to eliminate the danger of buckeye poison. There is a demand that the whole region of the Sierras be investigated with relation to its possibilities in honey production. Reports and the results of a few experimental colonies indicate that there are almost unlimited areas which promise to be excellent for commercial honey production, and which may be utilized by the beekeepers in the San Joaquin and Sacramento Valleys, who have suffered constant reverses during the past few years.

MISCELLANEOUS

Phenological records for the principal nectar-secreting plants in the United States are still being received. This work is handled largely through correspondence and progress is necessarily slow. All the records have been classified according to regions and plants, and many valuable data have been gleaned from old reports and correspondence in the files of the division.

Samples of beeswax known to contain no foundation and to be composed entirely of pure beeswax were obtained through the field stations and through individual beekeepers for the use of the wax laboratory of the Bureau of Chemistry and Soils.

A collection of unheated honeys from the principal commercial sources, and of samples of flowers from which these honeys were produced, is being assembled for transmittal to the State chemical laboratory at Bremen, Germany, for analysis of diastase content. The work conducted in this country indicates that the diastase content of a number of American honeys is considerably lower than that of some German honeys, and the German law requiring a diastase content above a certain minimum works a hardship on the producers and dealers in honey with a natural diastase content below the German requirements. It is hoped that these tests will help to overcome the prejudice against those honeys naturally low in diastase, which are now admitted to Germany only as second-class or inferior products.

The specifications of the United States grades for honey have been rearranged, and a revision of Circular 24, United States Grades, Color Standards, and Packing Requirements for Honey, is planned for the coming year.

Preparations are under way to equip a model honey-handling house at Somerset, Md. Through all the years since the establishment of the bee-culture laboratory such equipment has not been available, and its lack has made it impossible to undertake certain technological studies of honey which are of great importance to the industry.

Lack of funds and personnel has again made it necessary to refuse many calls to participate in meetings of beekeepers' organizations, although members of the division have attended a number of important meetings. In many cases the organizations in question assumed part of the travel expenses.

Many requests have been received for photographs and information for the use of special writers, and educational material on bees and honey has been furnished to schools and the press in more than the usual quantities. Numerous radio talks on bees and honey have been prepared and broadcast over several of the national radio chains. Demands for manuscripts for radio talks have materially increased.

The library and bibliography of beekeeping literature have been constantly added to. Numerous requests have been received for special bibliographies, and these have been supplied. The old, important beekeeping literature is becoming scarce owing to the demand for it brought about by the establishment of several new beekeeping libraries.

TAXONOMY AND INTERRELATIONS OF INSECTS

TAXONOMY

The investigations under this unit have continued under the direction of Harold Morrison.

The service character of the work has continued to dominate the activities of the specialists in the unit. It concerns the identification of insects in all orders, and is of benefit to all branches of the Government service, as well as to officers of State experiment stations, university staffs, and many individuals interested in entomology both in this country and abroad. During the year a total of 17,430 identifications were made by members of the staff or by affiliated workers. These identifications were distributed as follows:

Group	Identifications
Beetles	4,407
Moths	2,565
Flies	2,259
Hymenoptera	3,240
Grasshoppers, etc	832
Ectoparasites and mites	590
Bugs	1,424
Scale insects	2,078
Miscellaneous	35
Total	17,430

The work of organizing and arranging collections to make them available for study and identification has been continued in practically all the groups during the year, but has been most active in Coleoptera (beetles). Renewal of the taxonomic work in the economically important group of Hemiptera (plant bugs) has been made possible by addition of two specialists to the staff. It is hoped to engage, very soon, a specialist for the group including mosquitoes and other blood-sucking flies. Taxonomy of the group containing cutworms and related moths, which includes many important farm and garden pests, has for some time been without the services of a specialist. Beginning with the next fiscal year it will be supervised by an entomologist transferred from the Mediterranean fruit-fly project of the Plant Quarantine and Control Administration. Negotiations have been completed for the transfer, early in 1932, of a specialist from the gipsy-moth work of the bureau to assist in taxonomic work on parasitic insects in the Braconidae group. Additional specialists are acutely needed for work on such economic groups as May beetles, click beetles (known in the larval stage as wireworms), and sawflies (a superfamily of Hymenoptera which includes destructive leaf-feeding and gall-making species), and to assist in the study of parasitic wasps and flies (Diptera). Lack of specialists for identification work in minor groups is now being met by such voluntary service as can be obtained on occasion, but can not be commanded, from amateurs and from other specialists.

In spite of the pressure of identification work, progress toward completion of taxonomic studies in many groups has been made. The extensive paper on the classification of coleopterous larvæ has been revised and perfected with a view to its early publication. The following papers have been completed and are ready for publication: A

long manuscript dealing with the Cerambycidae of the West Indies; one on the classification of certain tachinid flies; one describing certain new ichneumon parasites of beetles; a paper on North American chiggers and their classification; some papers discussing the results of field-survey work on chiggers and their hosts; and a paper presenting synoptic notes and describing new species of Hemiptera.

Papers on the following subjects have been completed and published: Revision of two genera of the Scolytidae; on the genus Perigaster (family Curculionidae); some short papers discussing the classification of Scarabaeidae or describing new species; and a paper on certain important bethylid parasites of stored-grain insects.

The Barnes collection of Lepidoptera, purchase of which was approved by Congress at the end of the last fiscal year, was transferred to Washington in August, 1930. The specimens and cases were transferred to the Smithsonian Institution for the United States National Museum in January, 1931. The library and some accessory equipment which accompanied the collection were retained by the taxonomic unit of the bureau. According to the inventory supplied with the Barnes collection, it includes approximately 473,000 specimens of North American and Mexican Lepidoptera, as well as important type and other material.

INSECT PEST SURVEY AND PUBLIC RELATIONS

The insect pest survey has continued under the direction of J. A. Hyslop. The work under the title "Public Relations" was authorized under the appropriation for the fiscal year 1931, but owing to difficulties in obtaining personnel was not actually begun until January of that year.

INSECT PEST SURVEY

The activities under this project are concerned with collecting, recording, analyzing, and maintaining permanent records of insect abundance and damage and the publication of a monthly bulletin on current insect conditions and an annual summary of these conditions throughout the United States. This information on insect conditions is supplied through cooperative arrangements with entomologists of the bureau, State entomologists, and others who furnish to this central unit notes on insect occurrence and injury within their own districts. This work is incidental to their other tasks. Maintaining these records and supplying current information on insect conditions is of decided benefit to entomologists and entomological work. The insect-pest survey now has some 94 special collaborators who report monthly, and arrangements have been made to secure information on entomological conditions in the Dominion of Canada, Guatemala, Honduras, Cuba, Porto Rico, Costa Rica, Haiti, Mexico, and the Hawaiian Islands. It also exchanges outstanding entomological information with the Dominion of Canada and the Hawaiian Islands, whose entomological agencies have local surveys similar to that of the Bureau of Entomology. During the year the insect pest survey completed Volume 10 of the Insect Pest Survey Bulletin and the first four numbers of Volume 11, including 560 pages in all.

During the year the insect pest survey added to its permanent record approximately 34,000 notes on domestic insects, covering

8,000 species and 2,500 genera, bringing the total number of notes to more than 112,000, and the number of genera concerned to 5,700. This record is now completely cross indexed according to host plants. Summary cards have been prepared under each insect to indicate its food plants, parasites, and predators, and, if it be a parasite or predator, its various host insects. Maps are in the files showing world distribution, United States distribution, and detailed State distribution of the more important insects.

PUBLIC RELATIONS

This project deals with extension work in applied entomology and is conducted in cooperation with the Office of Cooperative Extension Work and the extension specialists in entomology in the several States. It includes the preparation of educational material in entomology, the planning and supervision of the preparation of educational exhibits in entomology, and general contact work on entomology with motion-picture activities. For the purpose of contacts with the State officials the country is divided into four main districts, and an extension entomologist is assigned to each district to maintain contacts and to furnish the various State officials with the latest information on methods of control of insect pests.

MISCELLANEOUS RESEARCH SUBJECTS

INSECT MORPHOLOGY

In the field of insect morphology R. E. Snodgrass has completed the first part of a study of the morphology of the insect abdomen. Part 1 of this study, covering the general structure of the abdomen and its appendages, will shortly be published in Smithsonian Miscellaneous Collections. Mr. Snodgrass has also practically completed a study of the evolution of the insect head and organs of feeding, which will be published in the Annual Report of the Smithsonian Institution. He has three additional papers now in an advanced stage of preparation, all relating to the morphology of the insect abdomen, including the internal organs.

INSECT PHYSIOLOGY AND TOXICOLOGY

Important work in the general field of physiology and toxicology of insects has been carried on for a number of years in the various divisions of the bureau. During the year this work was established as an independent project serving all units of the bureau, emphasizing and specializing in basic work relating to the chemical control of insect pests. The activities carried on in this section are: (1) Investigations designed to determine basic facts of the physical effect of poisons on major insect groups, with the idea of developing practical leads for improving methods of controlling insects with insecticides; (2) investigations on the vital processes and secretive and excretive products; (3) studies on the behavior of insects under known environmental conditions, to establish a basis for actual determination of results of experiments on attractants, repellents, baits, etc.; (4) research leading toward standardizing methods of experimentation on the physiological reactions, with the purpose of im-

proving methods now used in outlining experiments carried on in the field; and (5) tests to determine the effectiveness of various insecticides such as stomach poisons, contact poisons, and fumigants, such tests being conducted under controlled conditions in the laboratory to evaluate insecticidal compounds or mixtures and to promptly determine those which promise to be useful under field conditions.

The centralization of these basic investigations is in the interest of economy and makes fundamental information available widely and promptly. An important part of this work is done in cooperation with the Bureau of Chemistry and Soils, particularly the testing, with suitable insects, of the various compounds submitted by that bureau.

The work in this field during the year has been somewhat interrupted by changes in personnel and by removal to a new laboratory in Takoma Park, Md. The section is under the direction of F. L. Campbell, with whom are associated a number of highly trained specialists, most of whom were transferred from other divisions of the bureau. Tests of compounds derived from rotenone and of other compounds related to rotenone, and of a series of fluorine compounds, have been made with appropriate insects. These tests were made for the Bureau of Chemistry and Soils. Perhaps the most important published work of the year was the report on the solubility of acid lead arsenate within the alimentary tract of the silkworm. An important phase of this study was the determination that it is possible, through the radioactive-indicator method developed by the authors, to obtain a better understanding of the toxicology of lead arsenate. Three other technical papers in this field have been published during the year.

BIOCLIMATICS

The special work in this field has been developed over a long period by A. D. Hopkins, who retired under the age limitation on August 31, 1931. Doctor Hopkins's service in the bureau covers many years, spent largely in the field of forest insects. He developed and established the Division of Forest Insects, but in later years became intensely interested in bioclimatics and has made it his special field. This work involves studies of the broad phases of the relations between insects and environmental conditions affecting their development and abundance. It includes application to the control of insect pests of the principles discovered through investigation. Publication of the more important results in this field is now possible, and the manuscript for such publication was substantially completed before his retirement. With the consent of the Department of Agriculture, Doctor Hopkins has been authorized to arrange for outside publication of this work, which is to be issued in two substantial volumes. Doctor Hopkins's interest in these investigations is such that he proposes to continue them for years, not only to complete the publication of the volumes referred to, but to carry forward investigation in full cooperation with the bureau. He has established, at his own cost, a laboratory and experimental grounds on his property on the Little Kanawha River, near Parkersburg, W. Va., which he hopes will become a permanent station for the study of bioclimatics, not only in relation to insects and their control, but in relation to plants and farm practices generally.

INSECT DISEASES

The study of insect diseases has not been broadly developed in the bureau, but it is very important and warrants extended research. While most insect diseases are influenced by climatic conditions, nevertheless a knowledge of such diseases and means of encouraging them may offer controls which in many instances are equal, if not superior, to those which may be obtained by chemical means or by the aid of such natural enemies as parasitic and predacious insects. G. F. White has continued to be the sole worker of the bureau in this field.

An important part of Doctor White's work this year has been the development, in cooperation with the Division of Insects Affecting Man and Animals, of methods and technic in securing and maintaining stocks of living blowfly larvæ in adequate numbers to be used in the postoperative treatment of osteomyelitis. This work has been done for the information of surgeons and hospital authorities. The extraordinary field of utility for such insect aids was developed by the late William S. Baer, of Baltimore. Doctor White has devised very satisfactory methods of breeding and preparing such material, and his work was made the subject of an exhibit at this year's session of the American Medical Association in Philadelphia. A publication is now being prepared for the purpose of making the description of the method generally available.

U. S. GOVERNMENT PRINTING OFFICE: 1931